VOL. 88, No. 1 MARCH, 1959

THE PHILIPPINE JOURNAL OF SCIENCE

MANILA
BUREAU OF PRINTING
1960

83719

THE PHILIPPINE JOURNAL OF SCIENCE

Published quarterly by the National Institute of Science and Technology
(Formerly Bureau of Science), P. O. Box 774, Manila, Philippines

// THE PHILIPPINE JOURNAL OF SCIENCE

VOL. 88 MARCH, 1959 NO. 1

A NEW AND ILLUSTRATED FLORA OF MANILA, I
ZINGIBERACEÆ

By MONA LISA STEINER
2838 Park Avenue, Pasay City, Philippines

THREE PLATES AND SEVEN TEXT FIGURES

INTRODUCTION

At present there is no "Flora" of Philippine flowering plants available; whatever has been published in this line has been out of print for many years. Father Manuel Blanco's *Flora de Filipinas* first appeared in 1837, the second edition was published in 1845, and the third edition, in 1877 to 1883. This last edition was printed in six large folio volumes with 481 hand-colored plates, but is now a collector's item, and found only in a few libraries. Although the nomenclature is in many instances obsolete, the work is still considered a valuable reference book.

In 1912 E. D. Merrill's Flora of Manila, the first concise "Flora" in English, was published by the Bureau of Science, complete with keys and descriptions of 1,007 species. The plants described are typical of nearly all inhabited regions at low altitude and serve therefore not only Manila, but most cultivated areas of the Archipelago. Unfortunately this important book, too, has been out of print for many years.

Since the publication of Merrill's Flora of Manila, 46 years have elapsed, and in this time the introduced elements have changed to a considerable extent. Numerous plants not only have been introduced, but have become established, some even escaping cultivation. To bring this Flora up-to-date, the author has studied for the last 20 years the plants around Manila and its suburbs. For several years she has actively engaged in

83713

cultivating ornamental plants and has established a commercial nursery—Mona's Botanical Garden—where she has collected and studied cultivated plants. A popular book "Philippine Ornamental Plants" has been the result of her studies. Later on she devoted more time to detailed studies, collected specimens for her own private herbarium and sent duplicates to the National Museum, Manila; the Smithsonian Institution, Washington; and the Rijksherbarium, Leiden.

During all these years she has kept detailed notes, sketches and photographs, and filed them for a revision of Merrill's Flora of Manila. Several years ago she asked Doctor Merrill for possible collaboration in a new and revised edition of his book. The famous botanist answered: "You are in the best position to do the work yourself, bit by bit. I would not worry too much, were I in your position, if I didn't get all the names correct—nobody can, the field is too vast. All one can do is to do the best that one can do under the circumstances."

With this encouragement in mind the author did her very best to verify nomenclature through the world's specialists such as R. E. Holttum for Zingiberaceæ, and checked also specimens in the Rijksherbarium, Leiden, the Naturhistorishes Museum, Vienna; and Kew, England. The revised nomenclature of this publication was based mostly on the monograph of Malaysian Zingiberaceæ by Holttum.

All plants described are preserved in the above mentioned herbaria. Only plants which have a fair distribution in at least six different localities and flower well in Manila and vicinity have been included. Three species have not been included in this family, because they have been noted only in two gardens, and it was not apparent that the plants would become established in the Manila area. Zingiberaceæ in Merrill's Flora of Manila comprises only 6 genera and 8 species; in this revision of the family, 11 genera and 19 species are described, or more than double the number in Merrill's. The author hopes to publish the whole Flora of Manila, family by family, richly illustrated, "bit by bit," as Doctor Merrill suggested.

It is hoped that after completion of all families these contributions will be combined into "A New and Illustrated Flora of Manila," a book useful to students as well as botanists and interested laymen for Manila as well as for most other lowland cultivated areas.

The author wants to express her sincere gratitude to Dr. Eduardo Quisumbing, director of the National Museum, Manila, for guiding and advising her since her arrival in Manila in 1938 in her studies of Philippine plants. Detailed drawings of the newly introduced species of Zingiberaceæ included here were furnished by this Museum through his kindness. Established or indigenous species that have already been amply illustrated in previous publications have been excluded.

Mr. Demetrio Mendoza, chief botanist of this Museum, also kindly assisted the author in numerous ways and went over the manuscript.

ZINGIBERACEÆ

Low or very tall perennial herbs, often aromatic, from sympodial, fleshy rootstocks, sometimes terminating in tubers. Stems simple, rarely branching, bearing leaves and inflorescence, sometimes flowers on separate stems, or acaulescent. Leaves simple, radical or cauline, usually distichous, sometimes spirally arranged, closely pinnately veined from a strong midrib. Sheath usually present, generally large, sometimes clasping the stem completely (Costus), ligule absent or present at junction of blade with petiole or sheath. Blades broad obovate to elliptic linear. Inflorescence in conelike heads, spikes, open racemes, panicles, rarely solitary, bracts and bracteoles subtending the flowers on alternate sides in a cyme, or in a cincinnus. Flowers irregular, perfect, usually lasting a day or less. Calyx tubular or bractlike, usually 3-toothed or lobed, often split on one side. Corolla tube long or short, the limb tripartite, marked differentiation of outer perianth series from the inner one. Perfect stamen only one, 1 to 4 petaloid staminodes usually present, often large and showy, sometimes small or wanting, staminodes may be joined in a more or less conspicuous labellum. Ovary inferior, not tuberculate, 1- to 3-celled, with axil placentation or with 3 parietal, rarely basal, placentas, ovules many. Stylodes often present. Style slender, filiform, and more or less enveloped in a channel of the filament, and often in the anther; stigma entire, protruding beyond anther. Fruit a 3-valved loculicidal capsule, or fleshy, indehiscent, berrylike, usually crowned by the remains of the perianth. Seeds numerous, arillate or not, small.

The family comprises about 47 genera and 1,400 species in the tropics and subtropics of the Old and New World; 3 genera

are restricted to Africa and 2 to Central South America, 40 occurring only in Asia or extending southward to Australia. only 2 genera are found in both the New and the Old World. There are about 17 genera and 70 species found in the Philippines. In Manila and surrounding area 11 genera are reported and 19 species; only five of them are native, six were introduced at an early date, and eight are of recent introduction.

Key to the genera of Zingiberaceæ

Leaves distichously arranged; leafsheath and ligule open.
  Ovary unilocular with parietal placenta.
    Corolla tube long, lip adnate to filament above corolla, filament much longer than corolla, slender; anther spurs pronounced, two or four .... 1. *Globba*
  Ovary trilocular with axillary placenta.
    Inflorescence terminating the leafy stem.
      Staminodes present; individual flowers surrounded by bracts and bracteoles.
        Lateral staminodes much broader than petals, free. Inflorescence a spike .... 2. *Hedychium*
        Lateral staminodes narrower and shorter than petals, attached to the sides of the lip above the base. Inflorescence a panicle .... 3. *Kolowratia*
      Staminodes absent or reduced to horn or awl-shaped excrescences. Individual flowers surrounded by bracteoles only, a few elongate bracts at base of inflorescence.
        Lip larger than other perianth segments; bracteoles deciduous .... 4. *Catimbium*
        Lip not larger than perianth segments; bracteoles persistent .... 5. *Alpinia*
    Inflorescence arising from the rootstocks or between tuft of leaves.
      All bracts strongly recurved, bracts laterally adnate forming a pouch .... 6. *Curcuma*
      All bracts not strongly recurved, mostly straight.
        Leaves radical, or very shortly stemmed, only two to five. 7. *Kaempferia*
        Leaves not radical, leafy stem long, more than eight leaves.
          Lip trilobed, broad and petaloid. Connective of anther prolonged into a narrow, curved beak. Inflorescence in ellipsoid spikes; all bracts similar. 8. *Zingiber*
          Lip not trilobed, narrow, fleshy. Connective not prolonged into a narrow, curved beak. Inflorescence in globes dense spikes, lower bracts much larger and strongly recurved .... 9. *Nicolaia*
Leaves spirally arranged, sheath and ligule tubular.
  Ovary 2-celled. Bracts vaginate, each surrounding several flowers.

Inflorescence loose, spirally arranged along the leafless stem, often continued by leafy stem .... 10. *Dimerocostus*

Ovary 3-celled. Bracts not vaginate, each covering one flower. Inflorescence compact in conelike spikes, terminating the stem. 11. *Costus*

Genus 1. GLOBBA Linnæus

Slender erect herbs with leafy stems from short fleshy rootstocks, covered with various sized scales. Leaves distichous, blades sessile or nearly so, ovate to lanceolate, basal part sheathing the stem, ligule short or lacking. Inflorescence terminal, on the leafy stem, erect or decurved, dense and spicate or racemose, or more lax and paniculate; bracts not tubular at the base, cincinni with 3 to 5 flowers. Flowers small, yellow or white. Peduncle slender, usually bearing a few sterile bracts instead of flowers, often bulbils developed. Calyx tubular, 3-toothed. Corolla tube slender, longer than the calyx, tube very thin, corolla lobes often boat-shaped, the dorsal one often terminating in a spur. Staminodes similar to the lobes, attached to the tube at the same level as the corolla segments, staminode segments as long or longer than the corolla segments, elliptic to oblong, not concave. Lip small, inconspicuous with two small auricles, base adnate at its edges to the stamen, forming a tube below, its limb free, narrow elongate, deflexed usually 2-lobed. Filament elongated, erect, slender. Connective of the anther extended laterally into an entire margin, or sometimes with 2 or 4 triangular spurs, anther crest not or only slightly developed. Ovary unilocular, parietal, with three placentæ and several ovules on each. Fruit crowned by persistent calyx, pericarp thin, seeds triangular, pubescent; capsule globose, smooth or verrucose, dehiscent. Not aromatic.

Species about 75, eastern Himalaya, southern China to New Guinea. About 11 species in the Philippines. The generic name is derived from "galoba" (Amboynese).

GLOBBA MARANTINA Linnæus.

Globba marantina LINNÆUS, Mant. 2 (1771) 170; PRESL, Rel. Haenk. 1 (1827) 115; SCHAUER, Nov. Act. Acad. Nat. Cur. suppl. 1 (1843) 427; LLAÑOS, Fragm. Pl. Philip. (1851) 7; F.-VILL. and NAVES in Blanco Fl. Filip. ed. 3 4 (1880) 2, Plate 351; NAVES, Novis. App. (1880) 219; VIDAL, Phan. Cuming. Philip. (1885) 151, Rev. Pl. Vasc. Filip. (1886) 274; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 156; RIDLEY, Philip. Jour. Sci. § C 4 (1909) 162; MERRILL, Fl. Manila (1912) 156, Sp. Blancoanæ (1918) 111, Enum. Phil. Fl. Pl. 1 (1925) 244; HOLTTUM, Gard. Bull. Singap. 13 (1953) 25; BAKH. JR., Fl. Java Fam. 84 (1958) 48.

Globba barthei GANGEP., Bull. Soc. Bot. Franc. 48 (1901) 208, Plate 7, figs. 1–4; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 159; RIDLEY, Philip. Govt. Lab. Publ. 35 (1906) 83.

Globba ectobolus K. SCHUM. in Engl. Pflanzenr. 20 (1904) 156, fig. 19.

Globba heterobracteata K. SCHUM. in Engl. Pflanzenr. 20 (1904) 159.

Bangliu (Ilk.); *barak* (Tag.); *luyan-luyaan* (Pang.).

Erect herb, glabrous to sparingly pilose, 25 to 60 cm high from slender, fibrous, sometimes spindle-shaped rootstocks. Stems rather loosely covered with sheaths. Leaves 3 to 7, ovate to elliptic, 8 to 15 cm long and 3 to 5.8 cm wide, acuminate, shortly petioled, glabrous above and somewhat puberulous beneath, ligule hardly 2 mm long, hairy. Inflorescence compact, spikelike, 2 to 3 cm wide and 4 to 10 cm long. Bracts persistent, ovate, green, gland-dotted, ciliate at the margin, 1 to 2 cm long, and 8 to 14 mm wide, the lower ones larger, not imbricating, open, not appressed. Several flowers open at a time, in the axils of upper bracts, lower ones frequently containing ellipsoid to conic bulbils in place of flowers. Bulbils about 1 cm long, surface irregularly warty when fully developed. Flowers about 5 cm long, very slender, yellow. Peduncles of secondary axis thin, 1- to 3-flowered, enveloped by bracteoles, elliptic-ovate 7 to 15 mm long, 3 to 10 mm wide. Calyx hairy at the base, narrow tubular, 3-toothed. Corolla tube much longer than the calyx tube, about 18 mm, very slender, segments oblong, shorter than the tube. Lip short, oblong, deeply bifid, narrow deflexed, cuneate. Staminodes longer than the corolla lobes, elongate, obtuse, about 5 mm long and 2.5 to 3 mm wide. Lip and filament united above the junction of corolla lobes. Filament about 18 mm long, incurved, anther 2.5 mm, anther cells narrow, winged on both sides, wings spreading, deeply 2-fid. Anther spurs 4, triangular, equal, about 2 to 3 mm long. Ovary slightly hairy, style about 4 cm long, stigma ciliate. Fruit smooth, ovate or globose, seeds 2, round with rough surface, wrinkled.

Iloilo Province, *Philip. Nat. Herb. 16439, 16345 Vallarta,* 1952; *33757, 33986, 33765 Taleon;* Mindoro, *Philip. Nat. Herb. 18938 Conklin,* 1953; Zambales, *Philip. Nat. Herb. 33239 Steiner.* Zambales, Fox No. 4789, 1948; Manila, Steiner No. 701.

In thickets, flowering from June to September; widely distributed about towns in the Philippines; introduced. Amboyna and Celebes to New Guinea.

Genus 2. HEDYCHIUM Koenig

Terrestrial or epiphytic herbs with elongated leafy stems from stout rootstocks. Leaves sessile or short-petioled, ligule small

or large, leaves oblong to linear or lanceolate, acuminate. Inflorescence terminal, often dense, in bracteate spike. Bracts oblong to obovate or lanceolate, imbricate or enfolding individual cincinni, persistent, several flowers to each bract. Bracteoles shorter than bracts; lower bracts often sterile, bracteoles tubular. Calyx tubular and 3-toothed, often hairy, much shorter than corolla tube, slender. Corolla tube very slender, lobes linear, lanceolate, spreading or reflexed. Staminodes broad and petaloid, often much wider than the petals, as long as corolla. Labellum large often suborbicular, obovate, more or less bilobed, clawed, broader than petals and staminodes. Filament elongated, much longer than anther, as long or longer than staminodes, anther with two conspicuous basal excrescences, connective at apex without excrescences. Ovary 3-celled, hairy, ovules axillary, in 2 rows in each loculus. Seeds numerous, capsule trilocular, loculicidal, splitting at the apex. Seeds with aril, divided deeply into many long irregular lobes.

Species about 43, center of distribution eastern Himalaya, southern India, Malaysia. Only one species native, *H. Philippinense*. *H. coronarium* probably introduced at an early date; *H. gardnerianum*, only of recent introduction.

Key to the species of Hedychium

Flowers white with yellow spot on lip, stamen yellow, filament shorter than staminodes .... 1. *H. coronarium*
Flowers yellow, with bright red stamen, filament longer than staminodes .... 2. *H. gardnerianum*

1. HEDYCHIUM CORONARIUM Koenig. Plate 1, fig. 1.

Hedychium coronarium KOENIG in Retz. Obs. 3 (1783) 73; MIQ., Fl. Ind. Bat. (1859) 608; NAVES, Novis App. (1880) 227; VIDAL, Phan. Cuming. Philip. 9 (1885) 152, Rev. Pl. Vasc. Filip. (1886) 274; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 44; RIDLEY, Philip. Jour. Sci. § C 4 (1909) 164; ELMER, Leafl. Phil. Bot. 8 (1919) 2978; MERRILL, Fl. Manila (1912) 157, Enum. Phil. Fl. Pl. 1 (1925) 241; DEGENER, Fl. Haw. Fam. (1938) 76; NEAL Gard. Haw. (1948) 215, fig. 105 a; QUISUMBING, Med. Pl. Phil. (1951) 191; HOLTTUM, Gard. Bull. Sing. 13 (1953); STEINER, Phil. Orn. Pl. (1952) 81, fig. 81; BAKH. JR., Fl. Java 48 (1958) 49.

Hedychium lingulatum HASSK., Pl. Hav. Rar. (1848) 135; NAVES, Novis App. (1880) 227; HORAN., Monogr. (1862) 25.

Kamia (Tag., Bik., C. Bis.); *katkatan* (Bis.); *katotang* (Bis.); *gandasuli* (Moro); white ginger (Engl.).

Erect herb about 0.7 to 1.2 m tall from aromatic rootstocks. Leaves oblong-lanceolate, acuminate 25 to 55 cm long, and 4 to

9 cm wide, glabrous, lower surface hairy along midrib. Ligule prominent, 2 to 3.5 cm long, hairy along margin. Spike ellipsoid, obovate, bracts ovate, rounded to acute, strongly imbricate, subcoriaceous; lower bracts mostly sterile 4 to 6 cm long, margin hairy, higher ones broad-linear with 2 to 3, seldom 5, flowers. Bracteoles 2 to 3 cm long. Flowers very fragrant, white with yellow spot on lip. Calyx tubular, about 4 cm long, corolla tube slender about 8 cm long, lobes linear-lanceolate, involute, about 3.5 cm long. Lip obcordate or obovate, white with yellow center, less than one-half bicleft, 4.5 to 5 cm wide and about 5.5 cm long, lobe 1.8 cm deep, lobes rounded. Lateral staminodes about 5 cm long and 2.2 cm wide, slightly notched at the apex, obovate, narrowed at the base. Stamen about 4.5 cm long, filament 3.3 cm, anther 12 mm long, curved, orange-yellow, basal excrescences about 3 mm. Stylodes 5 mm long, 1.5 mm wide. Capsule seldom produced here, oblong, 3 cm long and 1.5 cm wide, waxy, valves reflex slowly, inside orange, seeds bright red, very shiny, 4 mm long, 2.5 mm wide.

Laguna, *Philip. Nat. Herb. 8278 Sulit*, 1945; Lanao, *Philip. Nat. Herb. 19636 Brittan*, 1953; Quezon City, *Philip. Nat. Herb. 18088 Mendoza*, 1953. Pasay, Steiner No. 1543, 1955.

A native of India, now frequently cultivated in the Philippines and also naturalized. Buds unfurl in the late afternoon and close about noon the next day. Of prehistoric introduction in Mindanao, more recent in Luzon.

2. **HEDYCHIUM GARDNERIANUM** Roscoe. Plate 1, fig. 2.

Hedychium Gardnerianum ROSCOE, Monandr. (1828) 62; WALL., Kew Journ. Bot. 5 (1853) 369; Bot. Reg. 774; HORAN., Monogr. (1862) 25; REICHENB., Fl. Exot. 183; GARDNER, Chron. (1875) 461; O. G. PETERS., Fl. Bras. 9 (1893) 36; BAKER in Hooker f. Fl. Brit. Ind. (1849) 230; NEAL, Gard. Haw. (1948) 125, fig. 105 b.
Hedychium pallidum REGEL, Ind. Sem. Hort. Petrop. 9 (1856) 23; GARTEN, Fl. 13 (1864) 445; HORAN., Monogr. (1862) 25.

Yellow India ginger (Engl.).

Perennial herbs 1.2 to 1.6 m tall, leaves lanceolate to oblong lanceolate, attenuate, acuminate, 20 to 45 cm long, 4 to 5.5 cm wide, shortly petioled or almost sessile, ligule about 1.5 cm long membranaceous, leaves powdery white on the lower surface when young. Flowering spike 10 to 20 cm long, flowers laxly arranged, surrounded by enveloping bracts, 3 to 6 cm long. Bracteoles about half as long as bracts, tridenticulate. Flowers yellow with bright red stamen. Bracts separated, not over-

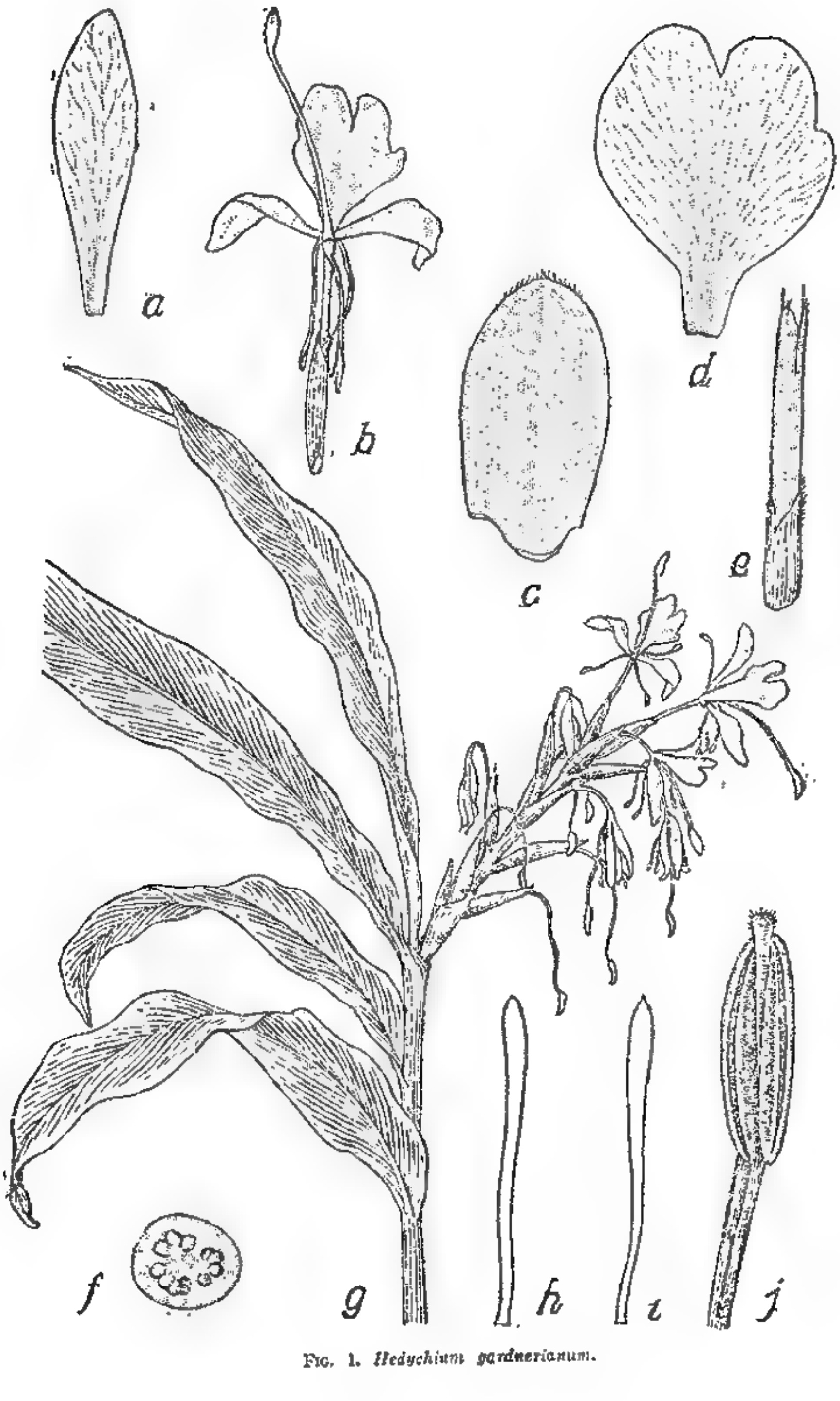


Fig. 1. *Hedychium gardnerianum.*

lapping, closely rolled around two flowers, concealing calyx and most of corolla tube; only one flower of cincinnus open at a time, but several flowers open on one inflorescence. Calyx 3 to 3.9 cm long, split on one side, apex tridentate, pilose. Corolla tube 5 to 5.5 cm long, lobes linear, acuminate, reflexed 3.5 to 4.5 cm long. Lateral staminodes oblanceolate 3 to 3.9 cm long, 1.5 cm wide. Labellum cuneate, strongly bilobed at the apex, nailed or clawed, 3 to 3.9 cm long. Filament 6 cm long, bright red, curved, anther 8 to 9 mm long. Capsule 1.8 cm long, red, inside purple, seeds 5 to 6 mm long with purple aril.

Quezon City, *Philip. Nat. Herb. 33318 Steiner*, 1955. Pasay City, Steiner No. 1429.

In forests of eastern Himalaya, Nepal, Sikkim, altitude between 1,300 and 2,500 m. Thrives and flowers well in Manila, but is more floriferous in Baguio and other high-altitude locations. Of comparatively recent introduction. Rare.

Genus 3. KOLOWRATIA Presl

Coarse tall plants from underground rootstocks. Stems stout, simple, leafy. Leaves oblong-ovate to lanceolate, large spreading or reflexed, petioled, ligule prominent, entire. Inflorescence terminal, branched, stiff, the branches short, rigid, scattered, clothed with large, oblong, persistent, rather stiff, densely arranged bracts, one flower opening at a time. Calyx spathelike, split down on one side, 3-toothed at the apex. Corolla tube short, slightly curved, the lobes broad, the dorsal one erect, concave, wider than the other two spreading or reflexed ones. Staminodes short, oblong or ovate, attached to the sides of the lip above the base. Lip obovate, slightly 3-lobed or subtruncate. Filament broad, fleshy, adnate to the corolla tube; anther elongated, grooved on the inner surface, the connective prolonged as a flat, ovate appendage. Ovary 3-celled; ovules many; style very slender, stigma obconic. Capsule ellipsoid, somewhat woody, ultimately splitting into 3 valves; seeds very numerous.

Species 3, all confined to the Philippines.

3. KOLOWRATIA ELEGANS Presl.

Kolowratia elegans PRESL, Rel. Haenk. 1 (1827) 113, Plate 20; MIQ., Fl. Ind. Bat. 3 (1859) 610; NAVES, Novis. App. (1880) 228; RIDLEY, Philip. Govt. Lab. Publ. 35 (1906) 86, Philip. Jour. Sci. § C 4 (1909) 181; MERRILL, Fl. Man. (1912) 159, Sp. Blancoanae (1918) 110, Enum. Phil. Fl. Pl. 1 (1925) 235; BROWN, Usef. Pl. 1 (1941) 430, fig. 173; QUISUMBING, Med. Pl. Phil. (1951) 195.
Kenealmia gracilis BLANCO, Fl. Filip. (1837) 1.

Renealmia exaltata BLANCO, Fl. Filip. ed. 2 (1845) 1, ed. 3 1 (1877) 2, Plate 1 *non* Linn.
Hellenia gracilis HASSK., Flora 47 (1864) 19.
Alpinia gracilis ROLFE, Journ. Linn. Soc. Bot. 21 (1884) 316; VIDAL, Phan. Cuming. Philip. (1885) 152, Rev. Pl. Vasc. Filip. (1886) 275.
Alpinia elegans K. SCHUM. in Engl. Bot. Jahrb. 27 (1899) 288, Pflanzenreich 20 (1904) 352, fig. 41 C; MERRILL, Philip. Govt. Lab. Publ. 27 (1905) 84, Philip. Jour. Sci. Suppl. 1 (1906) 37.

Bogombon (Tag.); *katkatan* (Bis.); *katotang* (Bis.); *salbak* (Tag.); *tagbak* (Tag.); *tugbak* (Tag.); kolowratia (Engl.).

A stout herbaceous plant, 2 to 4 m high, nearly glabrous, from stout rootstocks, stems swollen at the base, leafy throughout. Leaves coriaceous, spreading or reflexed, oblong-ovate to lanceolate, acuminate or caudate-acuminate, 25 to 60 cm long, 5 to 20 cm wide, the petioles stout, short. Inflorescence about 20 to 30 cm long, the base of the peduncle with an oblong-lanceolate, chartaceous, 8 to 12 cm long bract. Branches about 8, scattered, spreading, stout, about 5 cm long, covered with persistent bracts, each branch bearing several to many flowers, but only one opening at a time. Calyx about 4 cm long. Corolla pale straw-colored, about 7 cm long, the tube cylindric, the dorsal lobe about 4 cm long, concave, erect, the other two as long, but reflexed, oblong-ovate; lip about as long as the corolla lobes, spreading. Capsule ellipsoid, woody, 3 to 4 cm long, splitting into 3 valves, crowned by persistent calyx.

Mindoro, *Philip. Nat. Herb. 16830 Sulit*, 1952; Polillo Island, *Philip. Nat. Herb. 3456 Salvosa*. Laguna, Steiner No. 620, 1955; Novaliches, Mendoza No. 37423, 1957; Zambales, Fox No. 4580, 9165, 1949.

In thickets along streams at low and medium altitudes; widely distributed in the Philippines.

Endemic.

Genus 4. **CATIMBIUM Jussieu emend. Holttum**

Tall perennials with distichous leaves, the lowest without blades, sheathing; ligule prominent. Rootstocks fleshy, creeping, without tubers. Inflorescence terminating the leafy stems, erect or drooping, supported by a few very long, narrow lanceolate bracts at the base. Bracteoles enclosing the rest of the cincinnus, falling off after flowering, split half or almost to the base on the side towards the next flower. Inflorescence acropetalous, cincinnus 1 to 3 flowered, flowers of panicle numerous, several open at a time, calyx tubular, colored, often split on

one side towards lip, 3-dentate. Corolla tube shorter than the calyx, dorsal lobe wider than lateral ones, side lobes sometimes slightly spurred. Lip large, narrow at the base, more or less three-lobed, often with bifid apex, orange yellow with red markings, margin curved upwards. Staminodes short, slender, awl- or horn-shaped, sometimes missing. Stylodes conspicuous. Anther without crest. Ovary 3-celled, hairy, fruit round or depressed globose, indehiscent with thin wall. Seeds few or numerous, angular, surrounded by thin aril.

Key to the species of Catimbium

Inflorescence erect, flowers 4 to 5 cm apart on rachis, most flowers open at the same time, lip not more than 3.5 cm long.............. 1. *C. muticum*

Flowers in drooping panicles, closely set, gradually opening towards tip, lip about 5.5 cm long, horizontal.................................. 2. *C. speciosum*

1. CATIMBIUM MUTICUM (Roxb.) Holttum.

Catimbium muticum (Roxb.) HOLTTUM, Gard. Bull. Sing. 13 (1950).

Alpinia mutica ROXBURGH, Asiat. Res. 11 (1810) 354; NEAL, Gard. Haw. (1948) 221.

Renealmia mutica SALISB., Trans. Hort. Soc. 1 (1812) 280.

Languas mutica (Roxb.) DEGENER, Fl. Haw. 76 (1938).

Small shell ginger (Engl.).

Perennial herbs about 1.6 m high, growing in clumps, from aromatic branching rhizomes. Leaves glabrous, except hairy edges and midrib, about 25 cm long and 5 to 6 cm wide, apex caudate, falling off when mature, cauda about 2.5 cm long, ligule hairy, about 6 mm long, leafsheath 5 cm or less, brownish towards the margin, petiole about 2 cm long. Inflorescence an erect racemelike panicle about 6 to 15 cm long terminal, at base of uppermost leaf sheath, cincinni 1- to 3-flowered on hairy, reddish brown rachis, pedicels about 2.5 cm or more apart, most flowers open at the same time. Reduced small bracts, about 12 mm found only on the highest flower, other bracts absent, bracteoles white, soon falling off, about 1 cm long. Calyx funnel-shaped about 15 mm long with 2 to 3 irregular toothed lobes, hairy, split about half, white. Corolla tube shorter than calyx, lobes white, lateral lobes about 2 cm long and 1 cm wide, dorsal one 2 cm wide and 2.5 cm long. Labellum 3 to 3.5 cm long, broadly ovate, somewhat trilobed, sidelobes turned upward, margin wavy towards tip, yellow, spotted with fleshy dark crimson-red portions, sides plain yellow, apical portion lined with crimson. Staminodes absent. Filament 3 mm wide, 1.5 mm long, flattened pinkish towards the base; anther

without crest, about 14 mm long, enveloping the upper portion of the style, style filiform, curved, about 3.5 cm long, or less. Ovary pubescent, about 5 mm long. Fruit globose, bright red, 1.5 cm wide, 2 cm long, hairy, crowned by persistent calyx, indehiscent, breaking into three parts when opened. Fruits are regularly produced, and remain on the plant for a long time. Seeds dark brown, about 8.4 mm long with white thin, aril; aromatic.

Masbate, Steiner No. 1569, 1957.

Comparatively rare in cultivation. Flowering from July to August. Native to Eastern Asia.

2. CATIMBIUM SPECIOSUM (Wendl.) Holttum. Plate 1, fig. 5.

Catimbium speciosum (Wendl.) HOLTTUM, Gard. Bull. Sing. 13 (1950) 151.

Zerumbet speciosum WENDL., Sert. Hann. (4) 3 (1798) 19.

Renealmia nutans ANDR., Bot. Rep. 5 (1802) fig. 360.

Alpinia nutans ROSCOE in Smith, Exot. Bot. 2 (1805) Plate 106; NAVES, Novis App. (1880) 226; NEAL, Gard. Haw. (1948) 221, fig. 105e; STEINER, Phil. Orn. Pl. (1925) 81.

Alpinia cernua NAVES, Novis. App. (1880) 226, Fl. Filip. ed. 3 (1877–1883) Plate 464, *non* Sims.

Alpinia speciosa (Wendl.) K. SCHUM., Fl. Kaiser-Wilhelmsl. (1887) 29; ENGL., Bot. Jahrb. 27 (1899) 284, Plate 3, fig. A, B, Pflanzenreich 20 (1904) 339, fig. 40 D-F; STANDL., Contr. U. S. Nat. Herb. 17 (1928) 119.

Languas speciosa (Wendl.) MERRILL, Enum. Phil. Fl. Pl. 1 (1925) 234; QUISUMBING, Med. Pl. Phil. (1951) 197.

Lankauas na pula (Tag.); shell ginger (Engl.).

Very tall perennial herb from aromatic, branching rhizomes, yellow and pink when immature. Leafy stems in clumps about 3 to 3.5 m high, lower third of the stem bladeless, blades about 40 to 70 cm long and 12 to 14 cm wide, glabrous, acuminate-caudate, leaves subsessile or shortly petioled with conspicuous ligule, obtuse 1.5 to 2 cm long, hairy. Inflorescence terminal, a drooping racemelike panicle, flowers closely set, about 25 to 35 cm long on densely pubescent rachis subtended by 2 or 3 very long, acuminate, lanceolate bracts, flowers in cincinni of 2 or 3 flowers, peduncle 1 to 2 cm long, pubescent. Cincinnus enclosed by a deciduous glossy, white-purple tinged bracteole. Only 1 to 3 flowers open at the same time. Calyx subcampanulate 2.5 cm long, 3-lobed and split about 7 mm. Corolla lobes white, tipped pinkish, elliptic, 3.4 cm long, 12 mm wide, the dorsal lobe 3.5 cm long and 2 cm wide. Lip about 5.5 cm

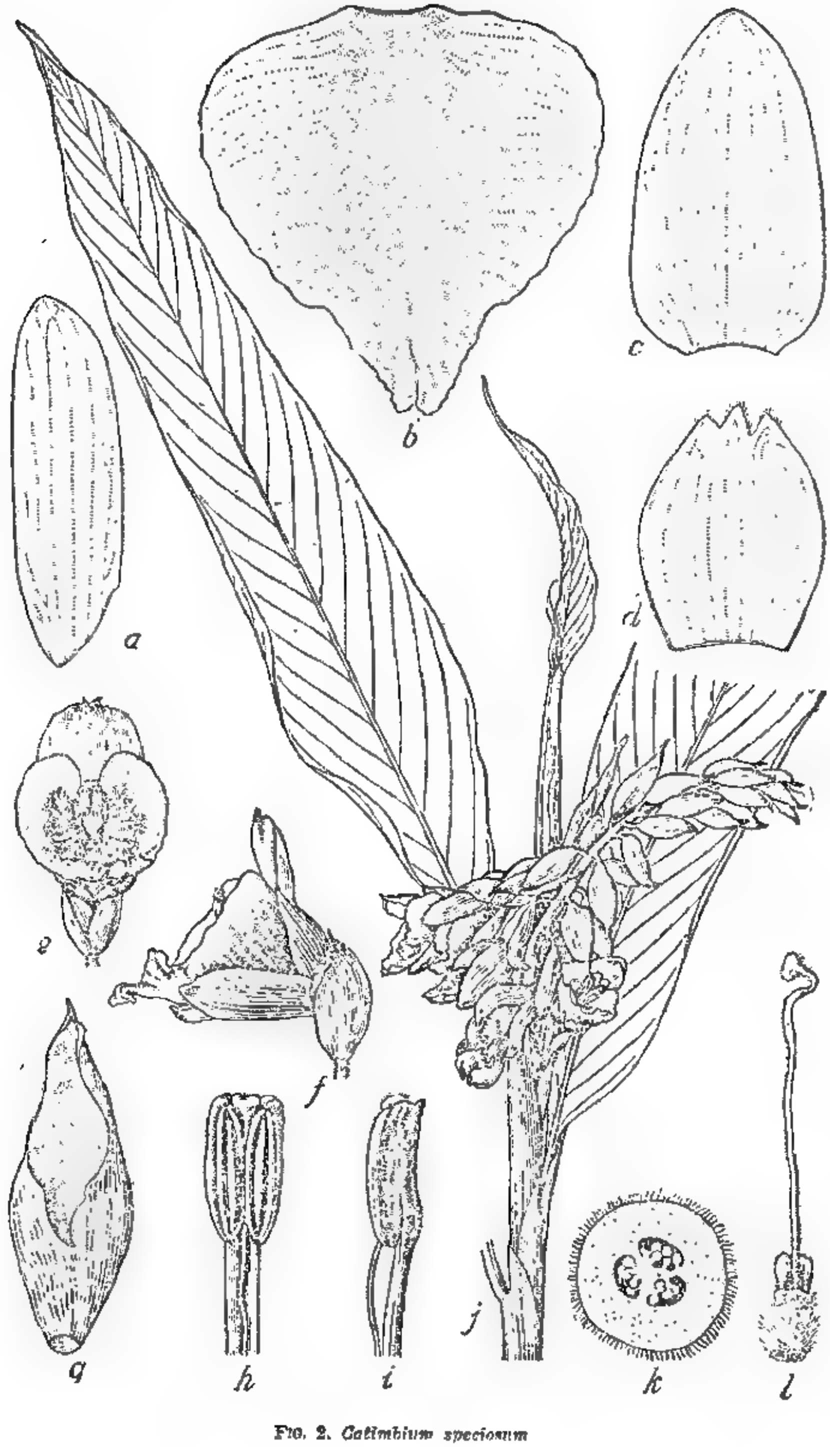


FIG. 2. *Catimbium speciosum*

long and 5.2 cm wide, laterally incurved, slightly bilobed at the apex, orange-yellow with crimson lines, 5 mm wide and 1.3 cm long, stigma yellow, protruding 2 mm above stamen. Ovary silky pubescent, 6 mm long and 4.5 mm wide. Style filiform encircled in the upper portion by the anther sac, stigma cup-shaped, 2 short stylodes at top of ovary. Fruit a capsule about 2 cm in diameter, dehiscent, seeds grayish, 3 mm. Seldom produced here.

Pasay City, *Philip. Nat. Herb. 34779, 35815 Steiner*, 1956. Pasay City, Steiner No. 805, 1365, 1955.

A native to Eastern Asia, plant is cultivated widely in tropical and subtropical countries. Commonly planted as an ornamental. It flowers mainly from February to July.

Genus 5. ALPINA Roxburgh

Strong-growing perennials with distichously arranged leaves from fleshy, creeping rhizomes, no tubers developed. Leaves usually petiolate, ligulate, lanceolate, leafsheath not closing around the stem. Inflorescence terminal, erect or drooping, in panicles, spikes or racemes, bracts usually rather small, but in some species large and persistent, lanceolate. Bracteoles numerous, more or less broadly funnel-shaped, cup-shaped or spathulate, persistent, often petaloid, each one enclosing the part of the secondary axis beneath it, secondary axis usually short. Flowers few. Calyx tubular or funnel-shaped, split, corolla tube long, but not longer than the calyx, lobes white or orange, lobes concave towards tip but not spurred. Labellum white or orange, or entirely orange with purple markings, sometimes broadly ovate and concave at base, three-lobed. Staminodes absent or sometimes present, variable in shape. Filament longer than the anther, anther sometimes crested. Stylodes two. Ovary 3-celled, fruit spherical or cylindric, more or less short hairy, crowned by the calyx. Seeds numerous, variable in shape, surrounded by aril.

About 240 species distributed over India, Malaysia, Oceania. One species commonly cultivated as an ornamental, particularly since World War II. The standing of *Alpinia purpurata*, the only representative, is not clear and needs further clarification.

ALPINIA PURPURATA (Viell.) K. Schum. Plate 1, fig. 3.

Alpinia purpurata (Viell.) K. SCHUM. in Engl. Pflanzenr. 20 (1904) NEAL, Gard. Haw. (1948) 221; STEINER, Phil. Orn. Pl. (1952) 80.
Guillainia purpurata VIELL., Bull. Soc. Linn. Norm. 10 (1866) 92.

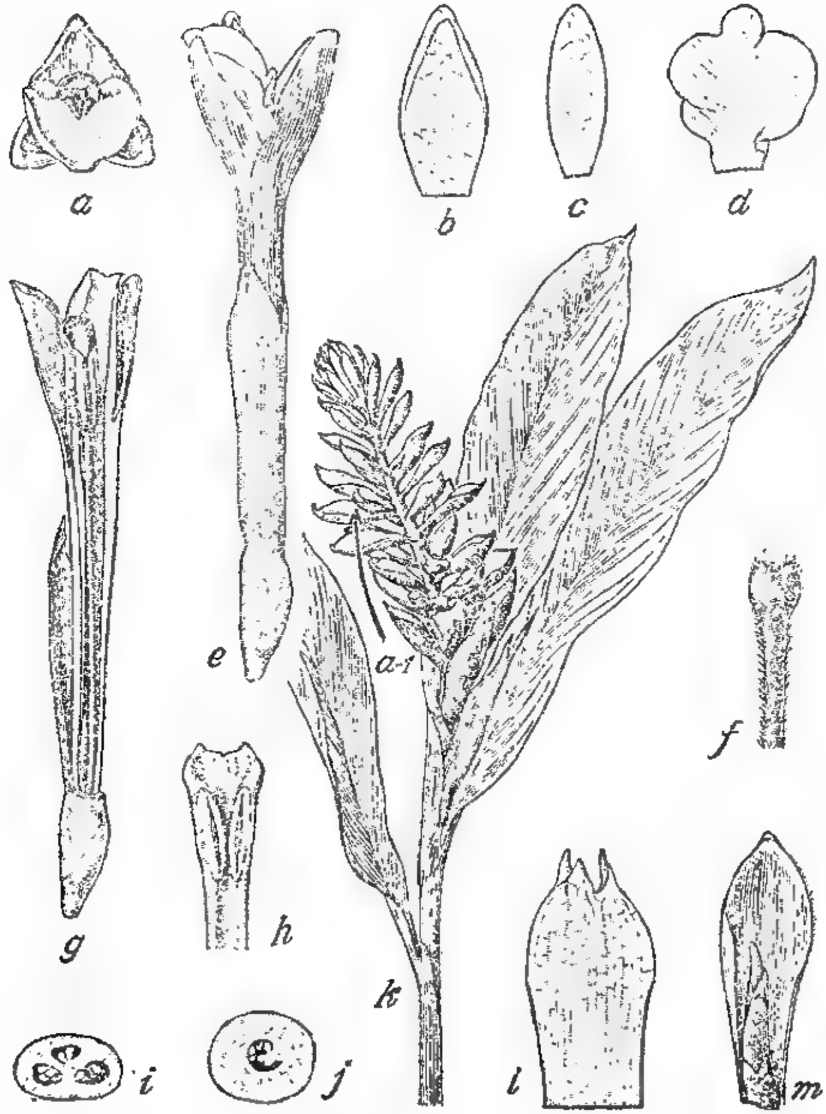


FIG. 3. *Alpinia purpurata*.

Alpinia grandis K. SCHUM. in Notizb. Berl. Gart. u. Mus. 2 (1898) 109, Engl. Bot. Jahrb. 27 (1899) 282, Plate 2, fig. 1–M.

Red ginger (Engl.).

Erect perennials 2 to 2.5 m tall, from creeping rootstocks. Leaves distichously arranged, 25 to 35 cm long and 10 to 12 cm

wide, ligule about 1 cm long, sheath 6 to 9 cm long, blades elliptic, lanceolate-oblong, acuminate, base attenuate, glabrous. Inflorescence terminal, more or less upright, sometimes curving downward, 15 to 40 cm long, subtended by 3 cm wide, lanceolate bracts up to 9 cm long, the lowest one longest. Inflorescence a raceme composed of bright red, persistent bracteoles, larger towards the base, spathulate, 2 to 4 cm long, 8 mm to 2 cm wide, abruptly acuminate, margin hairy. Flowers rarely developed. At apex or in axil of bracteoles often 20 to 25 bracteoles telescopically arranged, resembling a bud, white with reddish margin, becoming smaller towards the center. If removed a secondary axis develops. Calyx 18 to 20 mm long, red, 3 mm wide, tubular, split 8 mm, apex two-dentate. Corolla tube 22 mm long, lobes white about 8 to 9 mm long and 3.5 to 4 mm wide, elliptic ovate, obtuse, slightly cucullate, more or less of the same size. Labellum white, three-lobed, about 9 mm long, 5 mm wide, middle lobe rounded, longer than side lobes. Filament fleshy, partly connate with corolla tube, anther sac 4.5 mm long, 2 mm wide, connective appendage 2 mm long. Stylodes two, each two-lobed, filiform. In some flowers extra petaloid filament with extra theca present. Ovary unilocular in the upper part, 3-locular below. Fruit not formed here, only vegetative bulbils in the axil of bracteoles. Fruit is said to be 3 cm long, red, three-angled, glabrous, seeds exarillate, angled, 3 mm long, red. New shoots and plantlets often forming in the inflorescence.

Masbate Island, *Philip. Nat. Herb. 22605 Steiner,* 1954; Quezon City, *Philip. Nat. Herb. 37048 Parson,* 1956. Pasay City, Steiner No. 375, 1956.

Native probably to the Moluccas, Papua, Solomon Islands. A very commonly cultivated ornamental plant since World War II. Brightly colored inflorescences formed throughout the year, flowers rarely formed, only one open at a time during September and October.

Genus 6. CURCUMA Linnæus

Erect herbs from aromatic rootstocks, many bearing ellipsoid tubers; branching root-stem develops from primary rhizomes forming secondary and tertiary rootstocks; sometimes rootstocks not branching. Leaves distichous, oblong to oblong-elliptic or obovate, usually tufted. Ligule small. Leaves surrounded by bladeless sheaths often forming pseudo stems. Blades more or

less erect, petioles of outermost leaves short, inner ones fairly long, channeled. Inflorescence arising usually centrally from primary rootstocks, on separate stalks, conelike or in cylindric heads. Bracts large, broad, each joined to those adjacent to it for about half of its length, basal parts forming pockets, upper bracts often longer than the lower ones, spreading or recurved. Bracteoles thin, elliptic, enclosing the buds of the cincinnus; usually 2 to 7 flowers in a cincinnus, only one flower opening at a time, covered by bracteole and bract pouch. Calyx short, cylindric, nearly split halfway down on one side, toothed. Corolla tube broad, funnel-shaped, sometimes also split down on one side, 2- or 3-toothed, teeth ovate or oblong, dorsal corolla lobe often hooded. Corolla tube and staminal tube closed through 3 ringlike thickenings. Lip orbicular, obovate, entire, emarginate or 2-lobed. Stamen somewhat petaloid, filament short and wide, connective often terminating in a spur, anther versatile, filament and staminodes connate at base. Staminodes large. Connective of anthers sometimes forming a spur. Stylodes cylindric. Style glabrous, stigma short, funnel-shaped, more or less bilobed, hairy. Ovary 3-celled, hairy capsule membranaceous, globose, ellipsoid, 3-valved. Fruit dehiscent, seeds small, liberated in the mucilage of the bract pouch.

Species about 48, India to Malaya, 2 in the Philippines.

Key to the species of Curcuma

Corolla lobes tinged with purple; leaf with more or less feather-shaped purplish blotch in the center .... 1. *C. zedoaria*
Corolla lobes yellow; leaf without blotch in the center........ 2. *C. domestica*

1. CURCUMA ZEDOARIA (Berg.) Roscoe.

Curcuma zedoaria (Berg.) ROSCOE, Monandr. Pl. (1828) Plate 109; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 110; RIDLEY, Philip. Govt. Lab. Publ. 35 (1906) 84, Philip. Jour. Sci. § C 4 (1909) 166; MERRILL, Philip. Jour. Sci. § C 2 (1907) 438, Fl. Man. (1912) 158, Sp. Blancoanae (1918) 109, Enum. Phil. Fl. Pl. 1 (1925) 243; ELMER, Leafl. Philip. Bot. 8 (1919) 2977; BROWN, Usef. Pl. 1 (1925) 428; QUISUMBING, Med. Pl. Phil. (1951) 189; BAKH. JR., Fl. Java 48 (1958) 61.

Amomum zedoaria BERG., Mat. Med. (1788) 41.

Curcuma zerumbet ROXBURGH, Pl. Coromandel 2 (1798) Plate 101; NAVES, Novis App. (1880) 222.

Costus nigricans BLANCO, Fl. Filip. (1837) 3, ed. 2 (1845) 3, ed. 3 1 (1877) 5.

Costus luteus BLANCO, Fl. Filip. (1837) 4, ed. 2 (1845) 33, ed. 3 1 (1877) 6.

Roscoe nigro-ciliata HASSK., Flora 47 (1864) 21.

Alimpuyas (C. Bis.); *alimpuying* (C. Bis.); *barak* (Tag.); *bolon* (Tag.); *ganda* (Sbl.); *konik* (Ilk.); *koniko* (Bon.); *lampoyang* (P. Bis.); *langkuas* (Ilk.); *luya-luyahan* (Tag.); *tamahiba* (Tag.); *tamahilan* (Bik.); *tamo* (Pamp.); *tamokansi* (Tag.); *unig* (If.); zedoary (Engl.).

Rootstocks branching, fleshy, bearing ellipsoid tubers, aromatic, pale yellow, tubers curved upwards. Leaves 2 to 8, usually in pairs, erect, with a more or less feather-shaped purplish blotch in the center, elliptic-oblong to oblong-lanceolate, slenderly acuminate, blades 25 to 75 cm long, 10 to 16 cm wide, sheath and petiole about as long as blade. Flowering scape arises from the rootstocks, not in the center of leafy tuft, flowers are often formed before leaves appear. Spike about 6 to 15 cm long, 5 to 8 cm in diameter, peduncle 12 to 20 cm long and 3 to 5 cm thick, covered with a few bracts. Bracts broadly triangular, lowest ones blunt, upper ones more elongate, tipped with purple, lower ones more green, bracts joined to others for half their length forming a pouch, spreading, upper ones recurving. Five flowers in each bract, only one open at a time. Calyx 8 to 12 mm long, bifid, teeth short and broad, hairy, white with red teeth. Corolla about 4.5 cm long, tube yellowish white about 2 cm, corolla lobes ovate or oblong, obtuse, tinged with purple, 2.5 cm long and about 1 cm wide. Lip obovate, slightly bilobed, yellow sometimes with purplish margin, 14 to 18 mm by 14 to 20 mm. Staminodes 12 mm long, 10 mm wide, very pale yellow with a concave median fold. Filament about 4.5 mm long and almost as wide, anther 6 mm with divergent curved basal spurs, about 3 mm long. Stylodes 3 to 7 mm. Fruit hairy about 2 cm long.

Camarines Sur, *Philip. Nat. Herb. 2932 Convocar*, 1947; Laguna, *Philip. Nat. Herb. 22942 Steiner*, 1955; Leyte, *Philip. Nat. Herb. 35138 Frohne*, 1957; Laguna: Los Baños, *Philip. Nat. Herb. 15850 Lagrimas*, 1952; Rizal: Novaliches, *Philip. Nat. Herb. 30461 Mendoza*, 1954; *37422 Mendoza*, 1957; Rizal, *Philip. Nat. Herb. 20468*, 1954. Pasay City, Steiner No. 692.

Variable species very commonly distributed in thickets and open places, flowering from February to August, certainly introduced. Probably native of India, widely distributed in warmer parts of the Eastern Hemisphere.

2. CURCUMA DOMESTICA Valet.

Curcuma domestica VALET., Bull. Buitenzorg, 2nd. ser. 27 (1918) 31; RIDLEY, Flora 4 (1924) 264; NEAL, Gard. Haw. (1948) 217, fig. 105 C; HOLTTUM, Gard. Bull. Sing. 13 (1953) 68, fig. 4; BAKH. JR., Fl. Java 48 (1958) 63.

Curcuma longa LINNÆUS, Sp. Pl. ed. 1 (1753) 2; ROXBURGH, Asiat. Res. 11 (1810) 340, Fl. Ind. ed. 1 (1820) 32; BLANCO, Fl. Filip. (1837) 5, ed. 2 (1845) 4, ed. 3 1 (1877) 6, Plate 3; HORAN., Monogr. 9 (1862) 23; LINDL., Bot. Reg. Plate 88b; BAKER and HOOKER f., Fl. Brit. Ind. 6 (1890) 214; NAVES, Novis App. (1880) 221; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 108; RIDLEY, Philip. Jour. Sci. § C 4 (1909) 167; MERRILL, Enum. Phil. Fl. Pl. 1 (1925) 243; DEGENER, Fl. Haw. Fam. 76 (1938); BROWN, Usef. Pl. Phil. 1 (1941) 425; QUISUMBING, Med. Pl. Phil. (1951) 187.

Curcuma longa KOENIG in Retz., Obs. 3 (1783) 71, *non* Linn.; GAGNEP., Fl. Gen. Indoch. 6 (1908) 63.

Amomum curcuma JACQ., Hort. Vindob. 3 (1776) Plate 4.

Curcuma xanthorriza NAVES in Blanco, Fl. Filip. ed. 3 (1877), Plate 3, Novis App. (1880) 222, *non* Roxb.

Añgai (Pamp.); *barak* (Kuy); *dilao* (Tag.); *dulau* (S. L. Bis.); *kalabaga* (Bis.); *kalauag* (Mbo. Bis.); *kinamboi* (Bis.); *kulalo* (Pamp.); *kulyau* (Ilk.); *kunig* (Ilk.); *kunik* (Ign.); *lampuyang* (P. Bis.); *lauag* (Sub.); *luyang-dilau* (Tag.); *pañgas* (Pamp.); *salampauyan* (Bag.); turmeric (Engl.).

Acaulescent aromatic herb 60 to 150 cm high, from fleshy branching rhizomes of two forms: primary ellipsoid tubers, about 3 to 4 cm wide, ovoid, covered with persistent leaf bases, erect, inside deep orange-yellow with paler outer area. Secondary roots 5 to 8 cm long and about 2 cm wide, cylindrical with lateral distichous roots, pale yellow, covered with scales, grow mostly horizontal; the whole root system forming dense clumps. False stem composed of equitant sheaths about 25 cm long, leaves 30 to 40 cm long and 8 to 14 cm wide, acuminate, obliquely narrowed at base, oblong to elliptic, wholly green; petiole thin, abruptly broadening to the sheath. Ligule small, with ciliate edge. Inflorescence arising from the center of the leafy shoot. Peduncle about 15 to 20 cm long, inflorescence 10 to 15 cm long, spike erect, 6 to 7 cm wide. Bracts about 3 to 5 cm long and 2.5 to 3.5 cm wide, pale green and pinkish-violet towards the tip, ovate, inside white streaked, adnate half their length to the next bract, recurved; bracts near the tip more elongate-lanceolate, puberulous. Bracteoles 2 to 3 cm long. Flowers pale yellow, calyx 9 to 12 mm long, corolla tube about 2 cm, end lobes 10 to 15 mm long, petals whitish, corolla as long as bracts or longer. Labellum broad obovate, slightly bilobed, yellow, 16 to 19 mm long and 15 to 18 mm wide, creamy white with median yellow band. Staminodes narrowly ovate, obtuse 12 mm long, 8 mm wide. Stamen adnate to staminodia, filament 4 to 6 mm long, spurs of anthers very large, broad,

diverging. Ovary 3-celled, stigma with 2 ciliate lobes. Stylodes 5 to 6 mm. Fruits not seen.

Iloilo, *Philip. Nat. Herb. 16391 Soriano,* 1952; Luzon, *Philip. Nat. Herb. 14061 Edaño, 13394 Fox,* 1951; Manila: Ermita, *Philip. Nat. Herb. 1570,* 1956; Mindanao, *Philip. Nat. Herb. 18649 Conklin,* 1953; Mindoro, *Philip. Nat. Herb. 17482 Conklin,* 1953; Mountain Province, *Philip. Nat. Herb. 35567 Leaño,* 1957; Zambales, *Philip. Nat. Herb. 4921 Fox,* 1947.

Native probably to India, of pantropic cultivation; the rhizomes of turmeric or dilao are commonly sold in markets in Manila as food coloring and general dye, and also as seasoning. Plants are comparatively rare around Manila, more common in and around provincial towns. Widely distributed in the Philippines, sometimes in open waste places; often cultivated.

Genus 7. KAEMPFERIA Linnæus

Stemless herbs from aromatic tuberous rootstocks, usually of short elements, each bearing one to few leaves with terminal inflorescences, or leaves and flowers on separate shoots. Leaves few, suborbicular to ovate or lanceolate, basal or on short stems. Inflorescence spicate, shortly peduncled, erect, usually enclosed by imbricating leafsheaths, or by bladeless sheath, when it appears on leafy shoots. Flowers few to many, spirally arranged, white to violet, of short duration, each solitary in the axil of a bract and accompanied by a small, thin bifid bracteole. Bracts much longer than wide, their basis encircling a large part of the axis, closely imbricating. Calyx membranaceous, tubular, unequally toothed, corolla tube long and slender, lobes narrow, linear. Lip large, white or lilac, 2-lobed. Staminodes large, clawed, rounded, spreading. Filament none, or very short, anther sac hardly exerted beyond the throat of the flower, crest of connective usually large, entire or lobed. Ovary 3-celled, some unilocular. Capsule oblong, thin-walled.

Genus native to Africa and Asia, about 57 species, 2 in the Philippines. Named in honor of E. Kaempfer, an early Dutch physician and botanist. Flower and leaf production usually not simultaneous.

Key to the species of Kæmpferia

Leaves horizontal, broadly ovate almost orbicular, staminodes small, less than 3 cm long .... 1. *K. galanga*
Leaves erect, oblong, staminodes 5 cm long .... 2. *K. rotunda*

1. KAEMPFERIA GALANGA Linnæus.

Kaempferia galanga LINNÆUS, Sp. Pl. (1753) 2; BLUME, Roxb. Asiat. Res. 11 (1810) 327; HORT., Beng. (1811) 1, Fl. Ind. ed. 1 1 (1820) 15, Enum. Pl. Javae (1827) 47; ROSCOE, Monandrae 1 (1828) 92; WIGHT, Incon. 6 (1853) 899; HORAN., Monogr. (1862) 2; NAVES, Novis App. (1880) 222; BAKER and HOOKER f., Fl. Brit. Ind. 6 (1890) 219; K. SCHUM. in Engl. Bot. Jahrb. 27 (1899) 337; ENGL., Pflanzenr. 20 (1904) 77; RIDLEY, Philip. Jour. Sci. § C 4 (1909) 165; MERRILL, Fl. Man. (1912) 157, Sp. Blancoanae (1918) 110, Enum. Phil. Fl. Pl. (1925) 242; BROWN, Usef. Pl. Phil. (1941) 429; QUISUMBING, Med. Pl. Phil. (1951) 192, 193.
Kaempferia sessilis KOENIG in Retz. Obs. 3 (1783) 67.
Kaempferia humilis SALISB., Prodr. (1796) 6.
Kaempferia plantaginifolia SALISB., Trans. Hort. Soc. 1 (1808) 286.

Disol (Ilk.); *doso* (Bon.); *dosol* (Sbl.); *doto* (Bon.); *duso* (Tag.); *dusog, dusol* (Tag.); *gisol* (Tag., Pamp.); *kisol* (Buk., Bis.); *kosol* (Bis.); *kusol* (Pamp.); horizontal resurrection ginger (Engl.).

Small stemless herb from tuberous aromatic rootstocks, or sometimes with short stems. Leaves two or three, with short petioles spreading flat above the ground, aromatic, orbicular to broadly ovate, upper surface puberulous, lower surface pubescent or glabrous, acute, base rounded, 9 to 13 cm long, 6.5 to 10 cm wide, upper surface green, lower surface pale green; petiole 3 to 9 mm long; ligule very short, sheath below the ground, broadly channeled. Flowers 4 to 6, short-lived in a short spike, pink-lilac longitudinal bands in the basal half of the lip, staminodes white, aromatic. Bracts lanceolate, about 3.5 cm long. Calyx membranaceous, tubular, with 2-lobed apex, about 3 cm long; corolla tube slender, about 3.7 cm to 5 cm long, lobes 3.5 cm, white, linear, spreading. Lip cleft to the middle, 2.3 cm long and 2.5 cm wide. Two obovate staminodes 1.4 cm wide and 2.2 cm long, rounded, spreading, staminal-crest quadrate, 2-lobed, reflexed, lobes rounded, white, stamen projects slightly above the corolla tube.

Laguna, Sulit No. 14691, 1951; Mindoro, Conklin Nos. 14691, 19043, 1953; Mountain Province, Beyer No. 6856, 1948; Pasay City, Steiner No. 1055, 1957.

Widely distributed in the Philippines, cultivated and spontaneous, certainly introduced in open grasslands at low and medium altitude from India through Malaya to the Moluccas. Plant is used for culinary purposes, such as flavoring rice, and medicinal consumption. It flowers from July to September.

2. KAEMPFERIA ROTUNDA Linnæus.

Kaempferia rotunda LINNÆUS, Fl. Zeylanica (1737) 9, Sp. Pl. ed. 1 (1753) 3; ROSCOE, Monandr. (1828) 97; PETERS., Fl. Bras. 3 (1890) 35, Plate 10, fig. 2; BAKER in Hooker f., Fl. Br. Ind. 6 (1890) 222; K. SCHUM. in Engl. Bot. Jahrb. 27 (1899) 338; VALET., Bull. Buitenzorg, 2nd ser. 27 (1918) 109; RIDLEY, Fl. 4 (1924) 246, Bot. Red. Plate 60554, fig. 14; QUISUMBING, Med. Pl. Phil. (1951) 194; BAKH. JR., Fl. Java. (1948) 54.

Kaempferia vericolor SALLSB., Trans. Hort. Soc. 1 (1812) 286.

Gisol na bilog (Tag.); upright resurrection ginger (Engl.).

Leafy herb almost stemless, about 60 to 128 cm tall from tuberous aromatic rootstocks, white pungent, with subglobose tubercles. Leaves erect, about 3 to 5, elongate oblong-lanceolate, blade 10 to 30 cm long and 4 to 9.5 cm wide, sheath 25 cm long, blade pubescent on the lower surface, particularly along prominent midrib. Ligule membranous, very small, petiole channeled. Leaves purplish on the lower surface, on the upper side dark green, feathery-purplish variegated in the center, pale grayish green on the outside, side nerves prominent. Leaves only formed after flowering. Inflorescence sessile or short-stalked, surrounded by a few sheaths, flowers 4 to 16, borne on the almost flat apex of the axis, flowering bracts diminishing in size towards center of the inflorescence, the largest 3.5 cm long. Flowers acaulescent or shortly stalked, fragrant, corolla white, labellum lilac, paler towards edges, with white veins in basal part. Calyx 3 to 6 cm long, split on one side, apex shortly three-lobed, greenish or white, as long as the corolla tube. Corolla segments long-linear, acute, 4 to 7 cm long, 3.5 to 6 mm wide. Staminodes elliptic to linear, obtuse 3.5 to 5 cm long and 1.5 to 2 cm wide. Labellum deeply cut into 2 suborbicular lobes, the lobes curved downward, 4 to 7 cm long and 3 to 4 cm wide. Stamen up to 2.5 cm long, filament broad, anther crest 2 to 4 lobed, 5 to 10 mm. Generally not fruiting here.

Pasay City, Steiner No. 1571, 1956.

Plant is of comparatively recent introduction as an ornamental. It flowers from May to July. A native of India, and used there for flavoring food, and for medicinal purposes.

Genus 8. ZINGIBER Fabricius

Leafy stems, from fleshy, creeping aromatic rootstocks, tubers always absent, leafshoots close together. Leaves thin, medium sized, lanceolate to elliptic, distichous. Spikes on separate shoots, rarely terminating a leafy stem, usually peduncled,

flowering stems covered with bracts. Inflorescence thick cylindric, ovoid or tapering, elongating gradually. Flowers fugacious. Bracts of inflorescence imbricate, numerous, persistent, usually one flower in each bract, bracteole facing the bract. Bracts of inflorescence green or colored, often holding water, bracteoles shorter than bracts. Calyx tubular, often split on one side, 3-lobed, or 3-teethed, shorter than bracteoles. Corolla tube funnel-shaped, as long as bracts, dorsal lobe usually broader than the others, erect, narrowed to the tip and slightly hooded, lobes oblong to lanceolate, white or yellowish. Staminodes absent. Lip deeply 3-lobed, side lobes erect, middle lobe shorter than or not greatly longer than the lateral corolla lobes, apex usually retuse or cleft. Filament of stamen short and broad, anther long, narrow, connective of the anther prolonged into a curved beak. Ovary 3-celled; stylodes slender and free, not surrounding the base of the style. Fruit loculicidically dehiscent within persistent bract. Capsule thin-walled, splitting into 3 valves. Seeds black, arillate.

Species about 60, tropical Asia, Malaysia, Queensland to Japan, New Guinea; about 10 species in the Philippines.

Key to the species of Zingiber

Middle lobe of labellum not cleft; spike not more than 5 cm long, leaves less than 2 cm wide .... 1. *Z. officinale*

Middle lobe of lip cleft.

Inflorescence fusiform, acute, leaves 2 to 3.5 cm wide, ligule very short, 1 mm long, middle lobe of lip deeply cleft when mature, no liquid in conelike inflorescence .... 2. *Z. cassumunar*

Inflorescence with blunt tip, oblong; leaves 4 to 9 cm wide, ligule 1.6 cm long; middle lobe of lip slightly cleft; always mucilaginous liquid filling inflorescence .... 3. *Z. zerumbet*

1. **ZINGIBER OFFICINALE** Roscoe.

Zingiber officinale ROSCOE, Trans. Linn. Soc. 7 (1807) 348, Monandr. 9 (1828) Plate 83; MIQ., Fl. Ind. Bat. 3 (1859) 593; NAVES, Novis App. (1880) 220; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 170, fig. 23; MERRILL, Fl. Man. (1912) 159, Sp. Blancoanae (1918) 110, Enum. Phil. Fl. Pl. 1 (1925) 229; VALET., Bull. Buitenzorg. 2nd ser. 27 (1918) 128; BROWN, Usef. Pl. Phil. 1 (1941) 432, fig. 174; NEAL, Gard. Haw. (1948) 219; QUISUMBING, Med. Pl. (1951) 98; BAKH. JR., Fl. Java (1958) 10.

Amomum zingiber LINNÆUS, Sp. Pl. (1753) 1; BLANCO, Fl. Filip. (1837) 2, ed. 2 (1845) 2, ed. 3 1 (1877) 3, Plate 131.

Zingiber blancoi HASSK., Flora 47 (1864) 20.

Agat (Pang.); *baseng* (Ilk.); *laial* (Sbl.); *laiya* (If.); *laya* (Ilk., Bon. Ibn., It.); *luya* (Tag.); *gengibre* (Sp.); ginger (Engl.).

A slender, erect plant rising from thickened very aromatic, yellow to orange rootstocks. The leafy stems are 0.8 to 1 m high. Leaves distichous, linear-lanceolate 12 to 25 cm long and 8 to 15 mm wide, ligule 8 to 10 mm long, glabrous, petiole pubescent 2 to 4 mm long. Scape rising from the rootstock, 15 to 25 cm high, spike about 5 cm long and 2 cm wide, ovoid to ellipsoid, dense. Bracts ovate, cuspidate, about 2.5 cm long, pale green and 1.5 cm wide. Calyx about 1 cm long, corolla greenish-yellow, corolla tube 2 to 2.5 cm long, corolla lobes 1.5 to 2.5 cm long, 2 to 3.5 mm wide, acuminate. Labellum oblong-obovate slightly marked with purplish, middle lobe obovate, 12 to 15 mm long and about 13 mm wide, lateral lobes elongate, ovate 6 mm long and 4 mm wide, almost split to the base from the middle lobe. Anther about 9 mm long, anther crest about 7 mm curved downward. Stylodes 2, linear. Fruit not formed here.

Iloilo, *Philip. Nat. Herb. 33810 Taleon,* 1954; Laguna, *Philip. Nat. Herb. 33316 Sulit,* 1955; Polillo, *Philip. Nat. Herb. 15064 Fox,* 1948. Manila, Steiner No. 1547, 1956.

Probably native to India; commonly cultivated in the Philippines and other tropical countries as condiment; most valuable tropical rootspice. Flowering mostly from October to December.

2. ZINGIBER CASSUMUNAR Roxburgh. Plate 2, figs. 1, 3.

Zingiber cassumunar ROXBURGH, Asiat. Res. 11 (1810) 347, Fl. Ind. 1 (1820) 49; BLUME, Enum. Pl. Javae 1 (1827) 192; ROSCOE, Monandr. (1828), Bot. Mag. Plate 1426; HORAN., Monogr. (1862) 27; BAKER in Hooker f., Fl. Brit. Ind. 6 (1892) 248; VIDAL, Phan. Cumin. Philip. (1885) 152, Rev. Pl. Vasc. Filip. (1886) 274; NAVES, Novis App. (1880) 220; K. SCHUM. in Engl. Bot. Jahrb. 27 (1899) 268; RIDLEY, Philip. Govt. Lab. Publ. 35 (1906) 84, Flora 4 (1924) 259; MERRILL, Enum. Phil. Fl. Pl. 1 (1925) 229; HOLTTUM, Gard. Bull. Sing. 13 (1953) 58.

Zingiber purpureum ROSCOE, Trans. Linn. Soc. 8 (1807) 348; BAKH. JR., Fl. Java 43 (1958) 8.

Cassumunar ginger (Engl.).

Perennial herb about 60 cm to 2 m high from orange, pungent and bitter rhizome. Leaves distichous, oblong-lanceolate subsessile, apex acute, base cordate, 25 to 30 cm long, 2 to 3.5 cm wide, glabrous, only slightly pubescent on the lower surface towards the base, and short hairs along midrib. Ligule short, hairy near the margin, 2-lobed, about 1 mm long. Flowering scape 25 to 38 cm long, separate, flowering stalk clothed with long appressed sheaths, inflorescence 10 to 17 cm long, 3 to

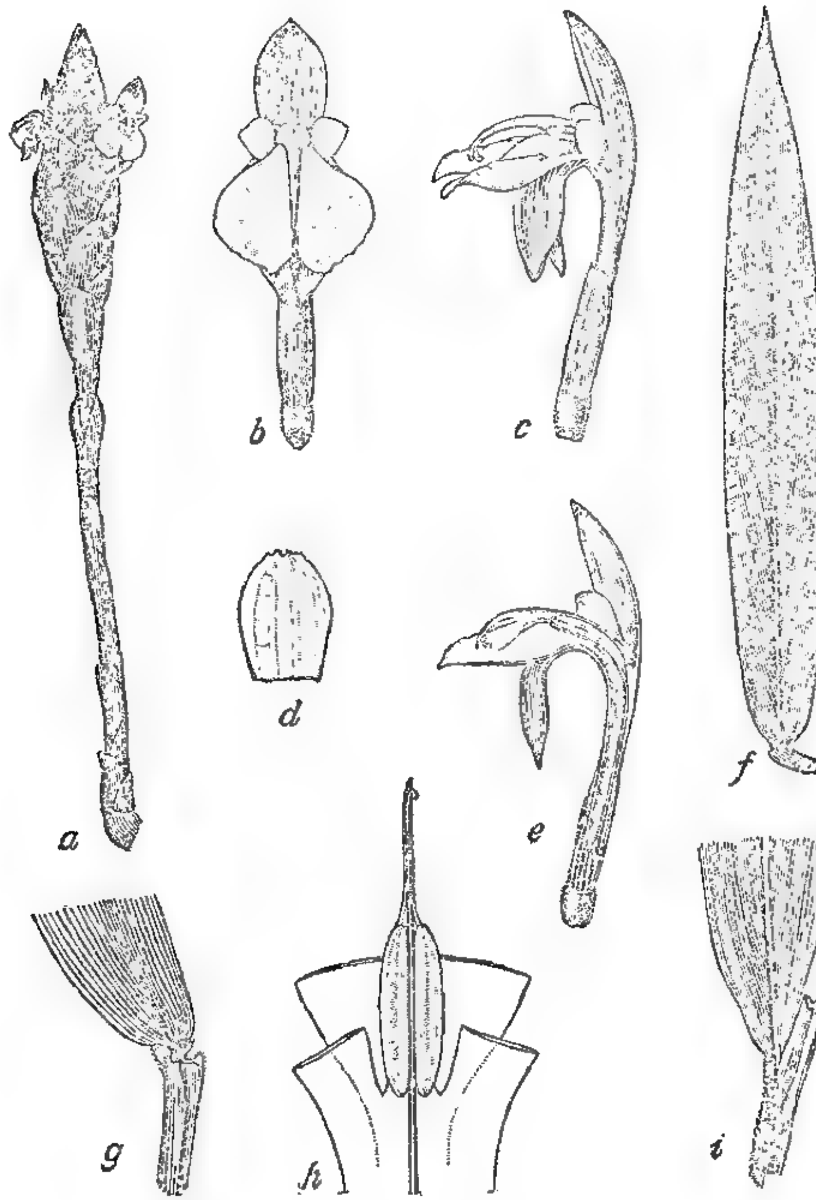


FIG. 4. *Zingiber cassamunar*, i, *Zingiber zerumbet*.

3.5 cm wide, fusiform, tip acute, covered with brick red bracts, seldom greenish here, 2.5 to 3.8 cm long and nearly as broad as long; lower bracts almost round, in the middle obovate lanceolate acute. Calyx 3 cm long, 3-dentate, split 1.5 cm deep. Corolla tube 2.8 cm long, 1.2 cm wide, corolla lobes ovate, lateral lobes 2.3 cm wide and 3.3 cm long, whitish. Lip very broad, slightly bifid in newly opened flowers, middle lobe deeply bifid when older, basal auricles large, obtuse, oblong. Labellum yellowish about 2.3 cm long and 1.3 cm wide. Stamen shorter or as long as lip, appendix of connective long, 8 mm, flexuous. Capsule subglobose, 5.6 cm long, seeds many, very small and purple.

Albay, Mendoza No. 18405, 1953, Sulit No. 16816, 1953; Batangas, Steiner No. 36962, 1956; Manila, Steiner No. 1064, 1956; Mindoro, Conklin No. 37451, 1957.

A native of tropical Asia, Mindanao and Luzon. Several collections are preserved in the National Museum, showing that this species is definitely found in the Philippines, although E. D. Merrill states that he had seen no specimens. Flowers and plants are sold in large quantities during the rainy season by flower stores and vendors. Most plants are said to come from Payapa, Malvar, Batangas Province. Originally this plant was cut and collected from secondary vegetation, but recently this species is being cultivated there to fill the local supply.

3. ZINGIBER ZERUMBET (Linnæus) Smith. Plate 2, fig. 2.

Zingiber zerumbet (Linnæus) SMITH, Exot. Bot. 2 (1804) 103, Plate 112; MIQ., Fl. Ind. Bat. 3 (1859) 593; NAVES, Novis App. (1880) 220; K. SCHUM. in Engl. Pflanzenr. 20 (1904) 172, fig. 24; RIDLEY, Philip. Jour. Sci. § C 4 (1909) 199; MERRILL, Fl. Man. (1912) 159, Sp. Blancoanae (1918) 111, Enum. Phil. Fl. Pl. 1 (1925) 229; BROWN, Usef. Pl. Phil. 1 (1941) 435; NEAL, Gard. Haw. (1948) 218, fig. 105 d; QUISUMBING, Med. Pl. Phil. (1951) 201; BAKH. JR., Fl. Java 48 (1958) 9.

Amomum zerumbet LINNAEUS, Sp. Pl. (1753) 1; BLANCO, Fl. Filip. (1837) 2, ed. 2 (1845) 2, ed. 3 1 (1877) 3, plate 370.

Zingiber zerumbet Smith var. *magnum* ELMER, Leafl. Philip. Bot. 8 (1919) 2922.

Balauag (Bik.); *barik, luiang-osin, langkauas, tumbong-aso* (Tag.); *layag sa-sulug* (Bik.); *tamohilang* (Buk.); wild ginger (Engl.).

An erect herbaceous plant, glabrous, from tuberous rootstocks, leafy stem 0.6 to 2 m high, leaves distichous, lanceolate to oblong lanceolate, 15 to 40 cm long, 4 to 9 cm wide, hairy beneath, apex acuminate, gradually narrowed towards base.

Ligule prominent, 1.5 to 3.5 cm long. Leaf sheath not overlapping. Leaves sessile or shortly petioled. Flowering scape separate, produced from the rootstocks, stalk about 25 cm long, about 9 mm wide, inflorescence 10 to 15 cm long, 4.5 to 5.5 cm wide. Peduncle covered with four to five pubescent sheaths slightly two-lobed at apex, joined about half the length, each sheath about 5 cm long, reddish at base. Inflorescence ovoid to oblong or cylindric, green or reddish, conelike obtuse, not acute at the apex. Bracts numerous, apex broadly rounded, orbicular, imbricate, greenish when young, turning red after flowering, holding a mucilaginous substance, bracts are 3 to 3.5 cm long and 2.5 cm wide, persistent, margin membranaceous, slightly hairy. Bracteoles 2.5 cm long and 1.3 cm wide, thin persistent. Flower about 5 cm long, tube as long as the bract, cream colored, calyx 13 to 17 mm long. Corolla tube 2 to 3.5 cm dorsal lobe 1.5 to 2.5 cm long and about 1 to 2 cm wide, lateral lobes narrower, ovate, acuminate. Lip almost orbicular, apex slightly cleft, middle lobe 2 cm wide and long, creamish yellow, deeper yellow towards base; side lobes smaller ovate, almost entirely separate from the middle lobe. Stamen as long as lip 8 to 20 mm long, appendage shorter than anther, about 7 mm. Fruit white, thin walled, glabrous, dehiscent, 8 to 12 mm long. Seeds ellipsoid, black, 5 to 6 mm long, covered with white aril.

Rizal, *Philip. Nat. Herb. 33339 Mendoza*, 1946. Batangas, Steiner Nos. 36961, 33181, 1956; Iloilo, Taleon No. 33770, 1954; Pasay City, Steiner Nos. 645, 1063, 1955; Polillo Island, Fox No. 9178, 1949.

Probably a native of India, now widely distributed in tropical Asia, wild and cultivated; probably introduced in prehistoric times in the Philippines, now very common, wild and in cultivation. Flowering from July to September.

Genus 9. NICOLAIA[1] Horan

Very tall, aromatic perennial herbs with stout stems and stalked leaves from creeping rootstocks growing closely to the surface, branching, no tubers present. Leafy stalks in clumps of 15 to 25 stalks, stems thickened at the base, reddish. Leaves distichous, with a well developed ligule, usually slightly 2-lobed.

[1] The generic name *Phaeomeria* Lindl. should not be retained, because Lindley did not supply a description [Nat. System. ed. 2 (1836) and K. Schum's description was published only 1904]. The valid genus should therefore be *Nicolaia* (Bl.) Horan. (1862).

Inflorescence on long peduncle from the base of leaf shoots, peduncle covered with 2-ranked sheaths, inflorescence capitate to conic-globose. Axis more or less widened or lengthened, head with an involucre of sterile bracts, large, colored, erect, or spreading. Floral bracts smaller, bearing very many narrowly tubular flowers closely together in a series of concentric circles, floral bracts narrow, thin, bracteoles tubular 2 or 3-toothed, deeply split, shorter than the calyx. Calyx narrowly tubular, 3-lobed, split down the other side. Corolla tube much shorter than the calyx, corolla lobes never shorter than the tube, about equal or longer. Lip erect, ovate, base joined to the stamen in a short tube, the tip extending somewhat above the corolla lobe and slightly deflexed, hardly spreads horizontally at the apex, after flowering lip rolls stiffly inwards in a spiral. Staminodes reduced to rudimentary teeth or humps, or lacking. Filament short, free anther long, emarginate at the apex, connective not enlarged. Style slender, stigma broad, with triangular opening. Stylodes short and fleshy, 3-partite, encircling base of style. Ovary 3-celled. Fruiting head round or elongate, fruits sometimes hairy, rounded or beaked, with thick pericarp, indehiscent.

About 25 species from Ceylon to New Guinea, 1 species in the Philippines.

NICOLAIA SPECIOSA (Blume) Horan. Plate 3, figs. 5, 6.

Nicolaia speciosa BLUME in Horan. Monogr. (1862) 32; VALE., Bull. Buitenzorg. ser. 3 (1921) 133; BAKH., Fl. Java 48 (1958) 46.

Elettaria speciosa BLUME, Enum. Pl. Jav. (1827) 51.

Alpinia magnifica ROSCOE, Monandr. Pl. (1828) 75.

Phaeomeria imperialis LINDL., Nat. Syst. ed. 2 (1836) 446; RIDLEY, Flora 4 (1924) 272, Philip. Jour. Sci. § C 4 (1909) 177; ELMER, Leafl. Philip. Bot. 8 (1915) 2907.

Phaeomeria magnifica K. SCHUM., Pflanzenr. (1904) 262; MERRILL, Enum. Phil. Fl. Pl. (1925) 241; NEAL, Gard. Haw. (1948) 219, fig. 107 a; STEINER, Phil. Orn. Pl. (1953) 83, fig. 84; HOLTTUM, Gard. Bull. Sing. 13 (1953) 181.

Tikala (Bukidnon); torch ginger (Engl.).

Very tall and fleshy perennial, about 2.8 to 3.8 m tall, in large clumps from strongly branching rootstocks. Leaves about 85 cm long and 18 cm wide, glabrous, lanceolate, apex acute, base broadly rounded, petiole about 3 cm long; ligule with hairy margin about 1.5 cm long, slightly bilobed. Flowering scape separate from leavy stem, 60 to 180 cm tall. Flowers in large red or pinkish conelike heads, composed of waxy, white margined bracts. Involucre bracts 8 to 12 cm long, 3 to 5 cm

wide, ends spreading or recurved, axis of inflorescence elongate 5 to 10 cm long. Bracts spirally arranged, showing a transition from involucre bracts to inner small, fertile bracts. Flowering bracts 3.5 cm to 4.8 cm long and 1.2 cm wide, obovate, obtuse, narrow at the base. Bracteoles about 2 cm long, 1.2 cm wide, membranaceous, deeply cleft, white with a red stripe in the middle of each lobe, split about 7 mm. Calyx 3.6 cm long, often 5-lobed, third lobe free, free lobe of calyx 2.3 mm long and 4 mm wide, falcate, obtuse, linear, two other lobes cleft 3 mm deep. Corolla lobes longer than calyx, 3 to 3.8 cm long and 5 mm wide, obtuse, pink in the center, white outside, corolla tube 1.9 cm long, dorsal corolla lobe connate with the base of lip about 1.9 cm, lateral lobes free. Labellum longer than corolla, deep crimson with yellow edge, paler towards the base, tubular at the base, middle lobe spatulate, about 4.4 cm long and 1.5 wide, side lobes upwards turned in a right angle, hairy at base. Stamen covering more or less the entrance of the lip. Filament 2.5 cm long, 2.5 mm wide, anther 7 mm long. Filament adnate to corolla. Stigma slightly protruding above anther, blackish red, 2.5 mm wide. Stylodes filiform, hairy in the upper part, about 3 mm long. Staminodes lacking. Fruit obovate, yellowish to reddish, 2 to 3 cm long. Seeds black in whitish, somewhat translucent pulp.

Laguna Province, *Philip. Nat. Herb. 12555 Quisumbing,* 1950; Mindanao, *Philip. Nat. Herb. 10217 Sulit,* 1949; Oriental Negros, *Philip. Nat. Herb. 6754 Edaño,* 1948; Quezon City, *Philip. Nat. Herb. 37041 Parson,* 1956. Masbate, Steiner No. 1546, 1957.

Found wild in Mindanao, but probably introduced. The larger flowering horticultural variety was introduced fairly recently from Hawaii and has been cultivated quite frequently in Manila since World War II. Also found in Java, Celebes, Malay Peninsula. Flowers throughout the year.

Genus 10. DIMEROCOSTUS O. Kuntze

Strong-growing perennials from fleshy rhizomes with spirally arranged leaves and tubular sheath. Inflorescence in dense spikes, only one flower opening at a time, bracts appressed, vaginate surrounding several flowers, persistent. Bracteoles winged on both sides. Calyx coriaceous tubulous, tridentate. Corolla tube short, narrow, lobes equally long, narrow, dorsal lobe wider. Labellum very wide obovate, concave, base involute. Staminodes lacking. Stamen petaloid, apex recurved,

closing the entrance to the flower, connective longer than the thecas. Ovary bilocular, cylindric, dehiscent, crowned by the calyx. Seeds numerous with four lines, angulate, surrounded by small aril.

Two species native to Ecuador and Bolivia.

DIMEROCOSTUS UNIFLORUS (Poepp.) K. Schum. Plate 2, figs. 4-6.

Dimerocostus uniflorus POEPP. ex O. G. PETERS., Fl. Bras. 3 (1890) 58; K. SCHUM., Pflanzenr. (1904) 427; STANDL., Contr. U. S. Nat. Herb. 17 (1928) 118; NEAL, Gard. Haw. (1948) 223.

Dimerocostus strobilaceus O. KUNTZE, Gen. 2 (1891) 688.

Cañagria (Sp.).

Plants robust, about 2.5 m tall, leaves oblong-lanceolate, 18 to 35 cm long, 4.5 to 6 cm wide, acuminate, sessile, margin wavy, ligule small, 5 mm, with long ciliate, lanuginose hairs, 2 mm. Sheath only 1 to 1.4 cm long. Leaves spirally arranged. Inflorescence often continued by leafy stem, spikes erect about 20 to 28 cm long, about 3 to 4 cm wide, flowers spirally arranged, only one flower opens at a time. Bracts appressed, vaginate, each surrounding several flowers, about 2 cm wide and 5.5 cm long, persistent, scarious. Bracteoles 1.5 cm long and 9 mm wide when flowering, about 2.2 to 2.5 cm long after flowering, sheath winged on both sides, green, later scarious, complanate, bracteoles more deeply lobed after flowering. Calyx 2.5 to 3 cm, trilobed, larger after flowering, persistent, tubular, green when flowering, later brown, lobes about 5 mm deep, not split on one side during flowering, sometimes afterwards. Corolla white, tube about 2.3 to 3 cm long, lobes oblong lanceolate, the two lateral lobes 4.6 cm long and about 7 mm wide, concave, dorsal, lobe about 5.8 cm long and 1.5 cm wide ovate. Labellum white, with yellow patch, wide obovate, margin undulate, 8 cm wide and 6 to 10 cm long, base involute. Stamen petaloid, apex recurved, about 6 cm long and 1.2 cm wide, anther 11 mm long, connective appendiculate, petaloid filament closes the entrance to the flower. Ovary 1.8 to 2 cm, bilocular, subcylindric, fruit a coriaceous capsule, 6 to 7 cm long, crowned by the calyx. Seeds narrow elliptic, grayish black, with four lines, arillus short.

Masbate: Steiner No. 1544, 1958.

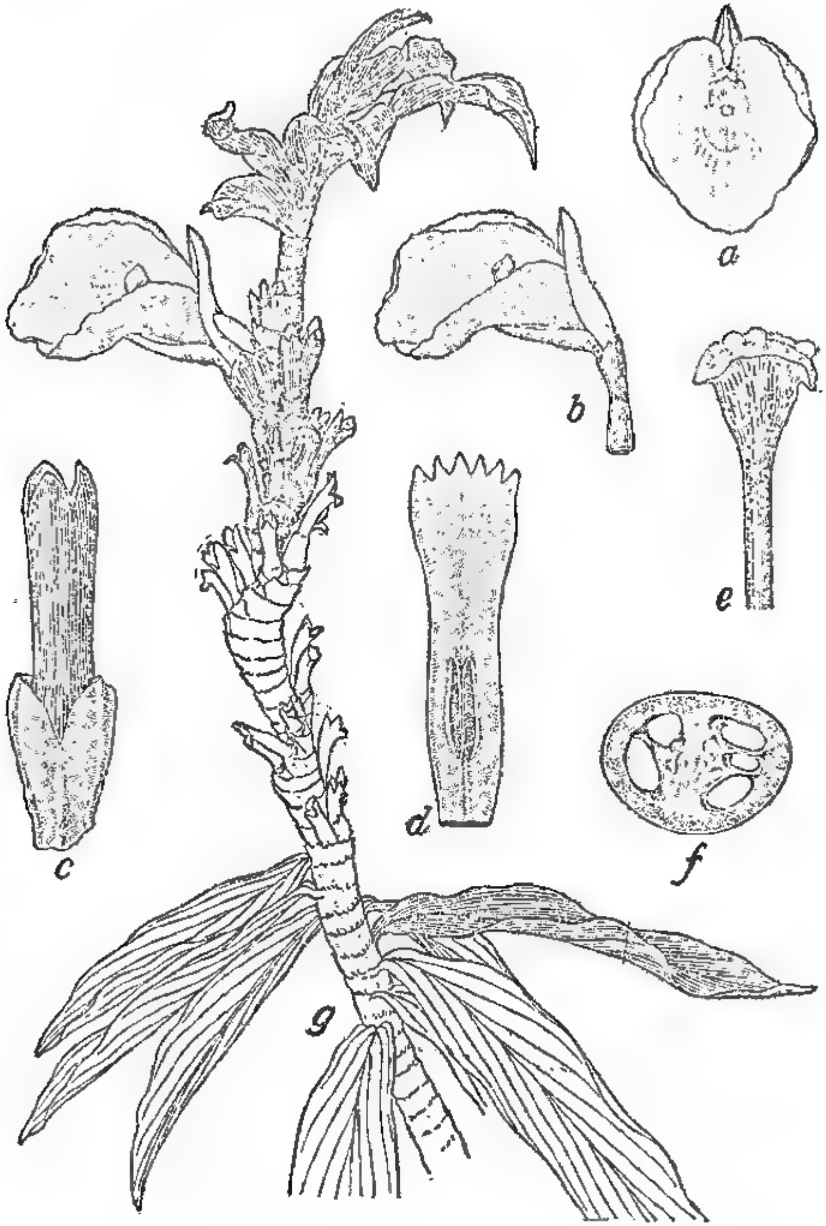


FIG. 5. *Dimerocostus uniflorus* (Poepp.) K. Schum.

Native to Panama and Ecuador. Was introduced first to Del Monte, Bukidnon, sugar central, from where some specimens were later on brought to Manila. Rare, flowering from August to September.

Genus 11. COSTUS Linnæus

Perennial herbs from creeping, sometimes tuberously thickened rootstocks. Stems spirally curving, sometimes branching, leaves oblong to lanceolate always spirally arranged, sheath entirely closed, branches breaking through the leaf sheath, ligule mostly circular, leaves shortly petioled or sessile. Inflorescence a dense conelike spike, terminal, sometimes new branches forming at tip of inflorescence, spikes rarely basal, one to a few flowers open at a time, base sometimes subtended by reduced leaves, crownlike. Bracts numerous stiff, imbricate, persistent with one or two flowers in axil of bract, bracteoles shorter than bracts. Calyx tubular, three-lobed, corolla tube broadly funnel-shaped, corolla lobes longer or shorter than calyx, oblong to lanceolate. Lip always showy, protruding over the bracts, more or less bilobed, obovate, somewhat spathelike, funnel-shaped at base, margins overlapping, crinkled at apex. The stamen broad and thin, petaloid, curved forward and closing the entrance to flower. Staminodes lacking, also stylodes, but usually 2 nectar-producing cavities at base of lip. Ovary 3-celled, ovules anatrope, capsule woody, loculicide, ovoid, split into three valves, crowned by persistent calyx. Seeds angular, pyramidical, albumen abundant, seeds numerous, black.

Species about 140 of the tropics of the Eastern and Western Hemisphere, about 9 species, in the Philippines, 5 introduced, 1 very rare.

Key to the species of Costus

Plants less than 60 cm tall.
  Leaves more or less crowded near the apex, broad ovate, flowers yellow-orange and red-lined .... 1. *C. malortieanus*
Plants more than 60 cm tall.
  Lip conspicuous, white, more than 4 cm wide. Common. 2. *C. speciosus*
  Lip inconspicuous, yellow, less than 4 cm only 9 mm wide. Rare. 3. *C. spicatus*

1. COSTUS MALORTIEANUS Wendl. Plate 3, figs. 1, 3.

Costus malortieanus WENDL., Hamb. Gart. Blumenz. 19 (1863) Bot. Magaz. Plate 5894; STEINER, Phil. Orn. Pl. (1952) 108, fig. 108; BAKH. JR., Fl. Java 48 (1958) 69.

Hairy costus, broad-leafed costus (Engl.).

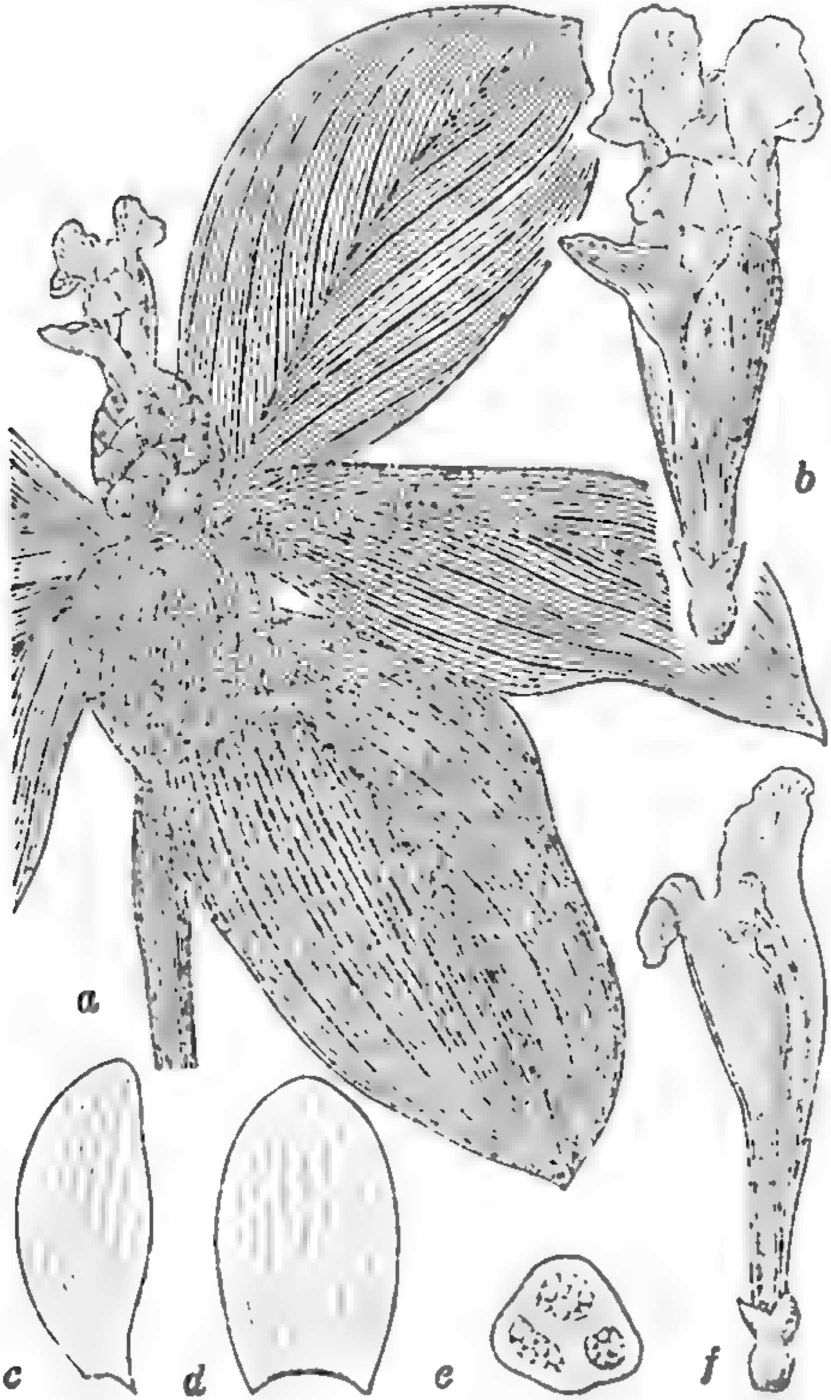


FIG. 6. *Costus malortieanus.*

Fleshy perennial herb, about 50 to 60 cm tall with spirally arranged leaves, closely set near the apex. Fleshy creeping rootstock, whitish green inside and pinkish outside, acid. Fleshy stem thickened, about 3 to 5 cm in diameter at the base, about 1.5 cm in the upper part, erect when mature, leafy stems reclining after flowering. Leaves obovate-elliptic 20 to 35 cm long, 13 to 28 cm wide, only about 1.5 cm apart when young, appearing almost verticillate after flowering. Petiole 1 cm or less, pilose, hairs on the upper surface of leaves 2.5 mm long; apex of leaves short acute, lower side of leaves pale gray-green, silky pubescent. Young leaves with 10 dark lines along the veins on the upper surface, disappear later. Leaf-sheath closing around the stem, ligule 2 mm, disappears later. Inflorescence a dense ovate, globose head about 5 to 8 cm long and 3.5 to 4 cm wide, stretching after flowering. Bracts closely appressed, green on the outside with numerous wine-red teeth about 3 mm deep. Corolla transparent whitish yellow, tube about 2 cm long, dorsal and lateral lobes 4.5 cm long, lateral lobes 1.8 cm wide, dorsal one 2.5 cm wide, elliptic-ovate, obtuse, erect, sides slightly incurved, especially dorsal lobe. Labellum adnate to corolla tube, 8 cm long and 5.5 cm wide when spread, middle lobe yellow with purplish brown stripes, side lobes cream colored with numerous reddish stripes, side lobes erect, middle lobe strongly recurved, divided into three cuneate portions together 2 cm wide, upright portion of erect side lobes above middle lobe 2.2 to 3 cm. Petaloid filament adnate to corolla tube, free portion 3.6 cm long, 1.2 cm wide, tip recurved, white with reddish lip. Anther 11 mm long, 14 mm below the apex. Ovary 9 mm long, white, glabrous, 7 mm wide, style 5.2 cm long. Fruit ovate, white about 14 mm long with thin wall. (Fruits seldom formed here.)

Pasay City, *Philip. Nat. Herb. 22741, 36965 Steiner,* 1956; Los Baños, *Philip. Nat. Herb. 15860 Gonzales,* 1952. San Juan, Steiner No. 1067, 325, 1954, Quezon City, 1955.

A native of Central America, frequently cultivated as an ornamental shade plant since World War II. Young plants often develop at the base of inflorescence.

2. COSTUS SPECIOSUS (Koenig) Smith. Plate 3, fig. 3

Costus speciosus (Koenig) SMITH, Trans. Linn. Los. 1 (1791) 249; ROXBURGH, Fl. Ind. ed. 1 (1832) 58; BLUME, Enum. Pl. Javae (1827) 61; WIGHT, Icon. Plate 2014; MIQ., Fl. Ind. Bat. 3 (1859) 610; HORAN., Monogr. (1862) 37; NAVES, Novis App. (1880) 227;

BLANCO, Fl. Filip. ed. 3 (1877–1883) Plate 442; BAKER in Hooker f., Fl. Brit. Ind. (1892) 249; K. SCHUM. in Engl. Bot. Jahrb. 27 (1899) 343; K. SCHUM. et LAUTERBACH, Fl. Deutsch. Schutzgeb. Suedsee (1900) 232; MERRILL, Fl. Man. (1912) 160, Enum. Phil. Fl. Pl. 1 (1925) 246; DEGENER, Fl. Haw. Fam. 76 (1938); NEAL, Gard. Hawaii (1948) 222, fig. 107 b; QUISUMBING, Phil. Med. Pl. (1951) 186; STEINER, Phil. Orn. Pl. 82; HOLTTUM, Gard. Bull. Sing. 13 (1953) 58; BAKH. JR., Fl. Java 48 (1958) 70.

Banksia speciosa KOENIG in Retz., Obs. 3 (1783) 75.

Costus nepalensis ROSCOE, Monandr. 20 (1828) Plate. 80.

Tububungiau (Bis.); *setawar* (Malay); spiral ginger (Engl.).

Tall, somewhat branching perennial from creeping rootstocks. Stems growing in clumps 1.7 to 2.8 m tall with curving branches, leaves spirally arranged, stems thickened at the base, in the middle about 13 mm wide. Leaves glabrous about 12 to 30 cm long and 40 to 80 mm wide, oblong, lanceolate, ensiform, tips curved downward, acuminate, petiole 4 to 7 mm long, base rounded. Young ligule circular with hairs about 12 mm long, ligule 3 to 4 mm long, hairs disappear when leaves mature. Sheath completely closed, pubescent 3.3 cm long, especially in the upper half, turning brown and dry after flowering, scarious. Inflorescence terminal ellipsoid, ovoid, flat at the top 6 to 9 cm long, bracts triangular ovate, acuminate, deep red, 2 to 3 cm long and about 15 to 20 mm wide, acute, concave, subtending laterally a bracteole about half the size of the bract. Only one or two flowers open at a time. Calyx flattened, red, somewhat scarious, about 25 mm long, 13 mm wide, elongates after flowering; calyx tube longer than the lobes, 3-lobed, frontal lobe the longest, 7 mm, dorsal lobe 4.5 mm long. Corolla white, membranous tube about 10 mm long, shorter than the calyx, corolla lobes 3, about 50 mm long and 28 mm wide, oblong-elliptic, abruptly acute. Lip membranous, broad suborbicular about 6.5 to 9 cm in diameter with crinkled margin, irregularly and finely toothed, white, deep yellowish hairs towards the center, sides at base overlapping to form flattened tube, lip connate at the base with filament. Filament hairy, about 5 to 6 cm long, 1.5 cm wide, fimbriate towards tip, anther 10 to 13 mm long, 3 mm wide. Ovary about 8 mm long, style filiform, white. Capsule 13 to 20 mm long, ovoid to globose, red, hairy, crowned by persistent calyx, seeds about 3 mm.

Philip. Nat. Herb. 2307 Convocar, 2504 Quisumbing; Albay: Mt. Mayon, *Philip. Nat. Herb. 18238 Mendoza,* 1953; Iloilo Province, *Philip. Nat. Herb. 16392 Soriano,* 1952; *22189 Aligaen,*

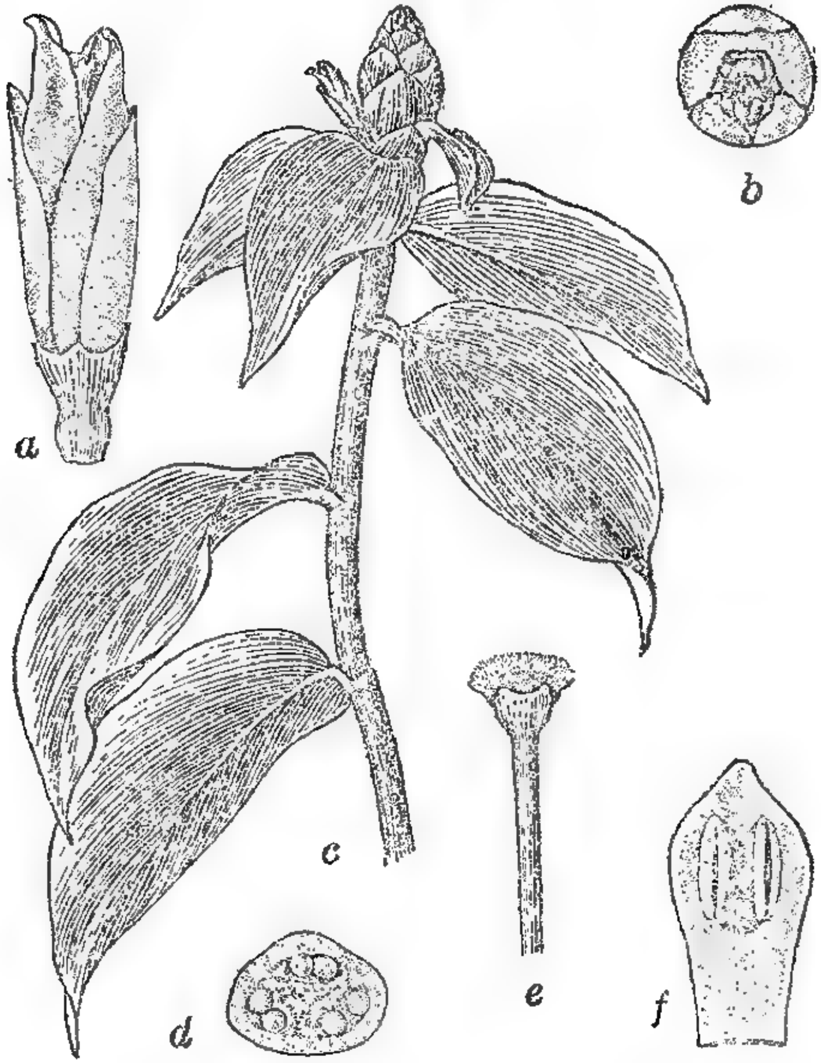


FIG. 7. *Costus speciosus.*

1953; Pasay City, *Philip. Nat. Herb. 36391 Steiner.* Pasay City, Steiner Nos. 1169, 1115, 1956.

Native of India, Formosa, Malaya, and New Guinea, widely distributed in the Philippines; wild variety smaller than stated above. Cultivated forms very variable, frequently encountered. Flowers mostly from September to January.

3. **COSTUS SPICATUS** (Jacq.) Swartz. Plate 3, fig. 4.

Costus spicatus (Jacq.) SWARTZ, Prodr. Fl. Ind. Occ. (1788) 11; ROSCOE, Monandr. Pl. (1828) 77; GRIESEB., Fl. Brit. West Ind. Isl. (1864) 602; STANDL., Contr. U. S. Nat. Herb. 27 (1928) 118; NEAL, Gard. Hawaii (1948) 223.

Alpinia spicata JACQ., Stirp. Amer. (1763) 1.

Costus arabicus AUBL., Pl. Guian. 1 (1775).

Costus quintus ROEM. et SCHULT., System. 1 (1817) 26.

Closed spiral ginger (Engl.).

Plants 1.2 to 1.6 m tall, stem 7 to 8 mm wide, leaves glabrous, 14 to 14.5 cm long, about 6 to 7 cm wide, petiole 3 to 5 cm, apex recurved, acuminate, base rounded, on lower side of leaves 8 to 10 dark stripes along the veins, sheath obliquely truncate, 4 to 4.5 cm long, ligule glabrous. Inflorescence terminating the leafy stem, an oviform spike with four leaves at the base in various sizes, 3.5 cm to 7 cm long. Spike 5 to 6 cm long and about 2.3 cm wide. Bracts coriaceous, broad ovate, bright red, appressed, about 2.5 cm wide and 2 to 3 cm long, concave, apex abruptly acute, inside whitish. Bracteole on right side of calyx, 1.8 cm long with red middle line and apex, white background, acute. Only one flower develops at a time, does not fully open; corolla, lip, and petaloid stamen remain somewhat tubular. Calyx 6 mm long, 6 mm wide, flattened whitish with red margin, slightly three-lobed, lobes rotundate, glabrous. Corolla tube 1 cm long, yellow, corolla lobes 2.8 cm long, 8 mm wide, bright red, enclosing almost completely the other parts of the flower. Lip erect, yellow, about 2.6 cm long, 9 mm wide, concave, apex obtuse, slightly three-lobed, curly. Petaloid filament lanceolate, obtuse, covers entrance to flower, 2.6 cm long, anther 6 mm long, 3 mm below apex; style 2.4 cm, stigma cup-shaped. Capsule three-lobed, puberulous, contains numerous seeds, angulate.

Masbate, Steiner No. 1545, 1957.

Native to Central America, Jamaica. Rare in cultivation, blooming from June to December.

ILLUSTRATIONS

[Line drawings are by Ricardo Aguilar of the Philippine National Museum. Photographs (Plates 1 to 3) are by the author.]

PLATE 1

PLATE 2

PLATE 3

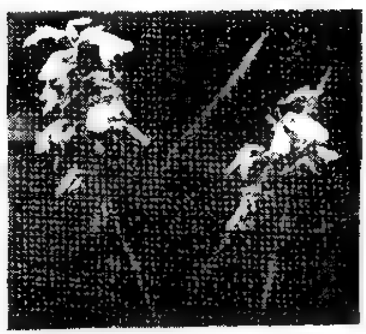
TEXT FIGURES

3. *Alpinia purpurata:* *a*, flower front view, × 3; *b*, lateral corolla lobe, × 3; *c*, dorsal corolla, × 3; *d*, labellum, × 3; *e*, flower, lateral view, × 3; *f*, stigma, × 3; *g*, longitudinal section of flower, × 3; *h*, anther sacs with connective appendage, × 3; *i*, cross-section of ovary, lower part, × 3; *j*, cross section of ovary, upper part, × 3; *k*, terminal inflorescence with a few bracts at base and numerous bracteoles, a-l, showing bud; *l*, upper portion of calyx, × 3; *m*, bracteole including young bulbil, × 3.
4. *Zingiber cassumunar:* *a*, inflorescence, × ½; b, flower, front view, × 1½; *c*, flower, side view, × 1½; *d*, calyx, × 1½; *e*, longitudinal section of flower, × 3; *f*, lower side of leaves, × 1; *g*, leaf with very short ligule, × 1; *h*, anther with elongated, curved appendage, style and stigma, × 3; *i*, leaf of *Zingiber zerumbet*.
5. *Dimerocostus uniflorus:* *a*, front view of flower, × ½; *b*, lateral view of flower, × ½; *c*, bracteole and calyx, × 1½; *d*, upper portion of staminode, × 1½; *e*, stigma, × 6; *f*, dimerous ovary, cross-section, × 3; *g*, leafy stem with inflorescence, × ½.
6. *Costus malorticanus:* *a*, leafy stem with inflorescence, × ½; *b*, front view of flower, × ½; *c*, lateral corolla lobe, × ½; *d*, middle lobe of corolla, × ½; *e*, cross-section of ovary, × 3; *f*, longitudinal section of flower, × 1.
7. *Costus spicatus:* *a*, flower, lateral view, × 2; *b*, top view of flower, × 2; *c*, leafy stem with inflorescence, × ½; *d*, cross-section of ovary, × 4; *e*, stigma, × 4; *f*, upper portion of staminode, × 4.

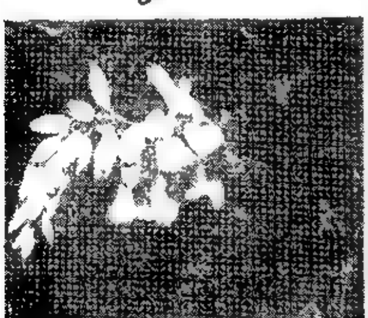
1

2

3



4



5

6

PLATE 1.

1

2

3

4

5

6

PLATE 1.

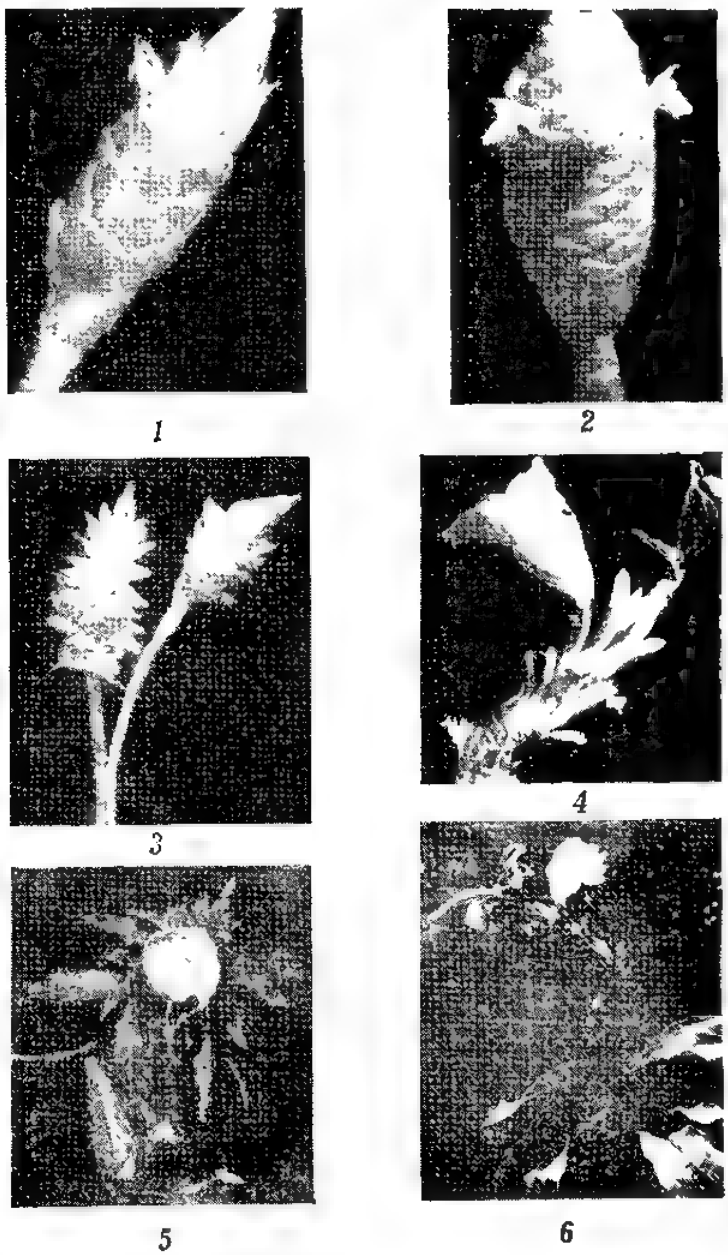


PLATE 2.

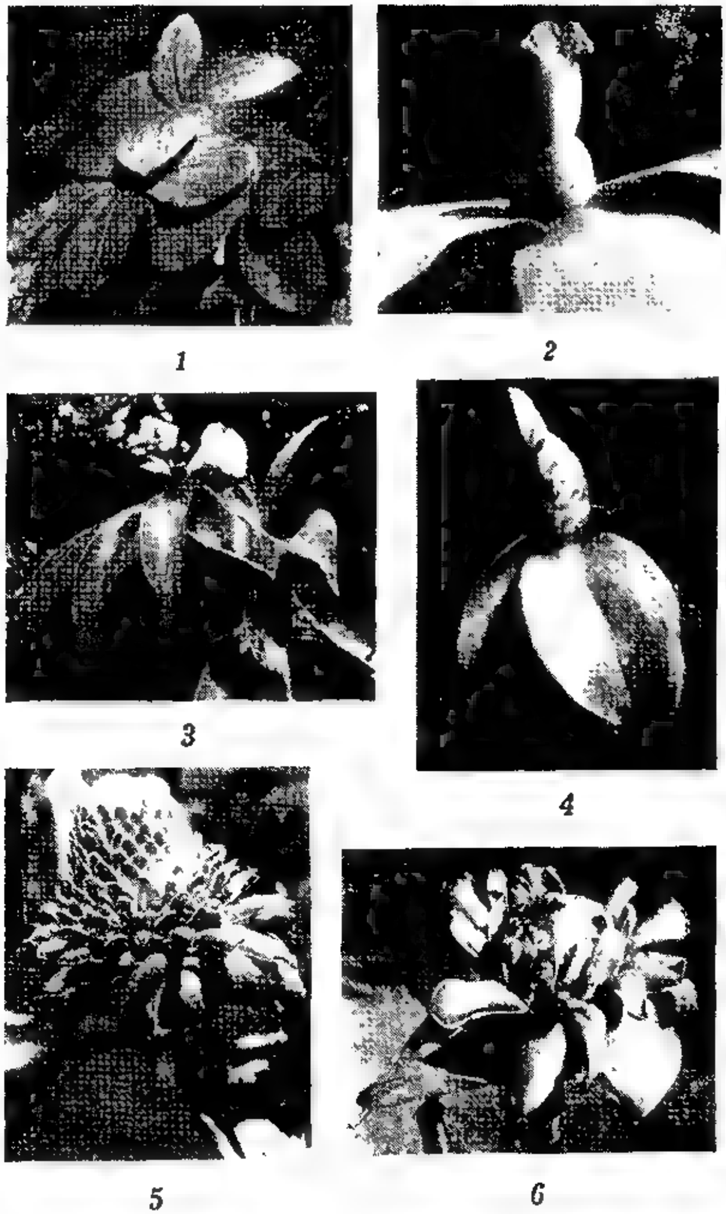


PLATE 3.

THE USE OF PHILIPPINE WOODS IN AIRCRAFT CONSTRUCTION

By ANTONIO J. DE LEON
National Institute of Science and Technology, Manila

TWO PLATES AND SEVEN TEXT FIGURES

As an aircraft construction material, wood is cheaper than metal. Although the waste in cutting wood is over 50 per cent, which is very much more than in metal, this is easily balanced by the fact that wood is easily and cheaply worked out. No elaborate equipment and production techniques are required in using wood. It can be worked out by the use of ordinary shop and hand tools. Highly specialized skills as those required in metal work are not needed. Repairs in aircraft wood structure can be easily accomplished, are more economical, and are done faster than in metal.

The combustible characteristics of wood and the danger of moisture absorption by insufficient surface protection render the use of wood objectionable. Moreover, the shear strength of wood perpendicular to the grain is rather low; but the characteristic under pure bending within the elastic limit is more favorable. In this respect wood is better than steel and other light aircraft metals as no permanent deformation is left under stresses up to its ultimate strength limit.

Wood has been extensively utilized abroad in aircraft construction during the last World War, where it was used in certain heavy bomber types like the British Mosquito and Lancaster. Even up to the present, most aircraft have used as much as from 20 per cent to 80 per cent wood for construction; and in small countries with limited aircraft production all-wood construction of light aircraft is still the general practice.

In the Philippines the metal industry is yet underdeveloped especially in that phase where metal is applied to aircraft construction. It becomes obvious that wood should best be used for this purpose. Until recently most of the woods used in airframes and aircraft overhaul and reconstruction work in the Philippines have been imported. These may now be slowly replaced with suitable local woods.

WOODS SUITABLE FOR AIRCRAFT CONSTRUCTION

There are several hundred assorted types of Philippine woods with varying characteristics and degrees of usefulness; but of the few more common species that are considered good substitutes of foreign woods and are generally used in aircraft construction, the following were selected principally in terms of availability, good strength and weight properties, cost, and workability:

1. *White lauan.*—White lauan (*Pentacme contorta* Merr. and Wolfe) is easily available commercially and the sources are abundant and well distributed throughout the Philippines. The wood is of light color, cross-grained, tough, takes bending loads well and is elastic. This wood can be used for most-stressed members of the aircraft. It does not warp easily and takes glue and nailing well. Wing spars and stringers can be built out of this wood. This wood is generally used as the outer face for good plywood manufacturing.

2. *Red lauan.*—Like white lauan, red lauan (*Shorea negrosensis* Foxw.) is commercially abundant. It has a reddish to dark-red color. The texture is somewhat coarse and the grains are crossed or interlocked. Red lauan is tough, hard and has relatively good bending-to-weight characteristics. Although seemingly heavy, this wood can be well adapted for highly stressed parts of the aircraft structure, such as the wing spars, stringers, bulkheads and seaplane floats. It can be used for the outer face panels in plywood manufacture and for wood-propeller construction on lighter types of aircraft.

3. *Tañgile.*—Tañgile (*Shorea polysperma* Merr.), is quite common and abundant in the islands. It is the local equivalent of mahogany and has a dark-red color. The grains are crossed or intermeshed. The wood is relatively hard and tough and gives a smooth outer surface finish. It is heavier than lauan. It can be used where highly concentrated loads are applied, and for reinforcements of fitting attachments. It is a suitable propeller material. It seasons evenly, does not easily warp and has good gluing characteristics. It is good for the manufacture of plywood, aircraft structural frames and bulkheads which are highly stressed. It takes shock loads well.

4. *Mayapis.*—Mayapis (*Shorea squamata* Merr.) is classified under red mahogany and like the others in the lauan family is widely distributed and abundant. It has a pinkish-red to

dark-red color. This wood has good strength and elastic characteristics and comes nearest to the North American spruce. Mayapis is light, has intermeshed grains, is relatively soft and easily workable. It does not easily warp. It is good for ribs and stringers and in its laminated form can also be used for stressed aircraft components, like the spars, frames, bulkheads and stringers.

5. *Kalantas.*—Kalantas (*Toona calantas* Merr. and Rolfe) is a kind of tropical cedar wood, soft and light, with light-pink to a dark red-brown color. The grains are interlocked and the texture is somewhat coarse. It does not take moisture easily and does not warp much. It is good material for wing ribs, auxiliary structural framework, reinforcing blocks, edges for wings and control surfaces.

6. *Palosapis.*—Palisapis (*Anisopter thrifera*) is abundant, widely distributed, and can be obtained commercially in quantities. This is a hard and rather heavy wood with the grains weavy but not so closely intermeshed as those in the lauan family. It has a light leatherlike color with pink or rose streaks. In well seasoned condition, it is durable and has good strength and elastic properties. It makes a smooth surface finish. It is good for spars and highly stressed aircraft members. It can be used for propeller construction.

7. *Manggachapui.*—This wood (*Hopea acuminata*) is a heavy, hard sort of wood of light grayish yellow to golden brown color. The grains are more or less straight with slight intermeshing. Smooth-grained manggachapui is more prominent when cut from young timber but tends to become knotty when taken from much older trees. The wood is smooth and of fine texture, quite durable, and has high bending strength and elastic qualities. It also takes shock loads well and is tough. Its good strength qualities make it a fine material for wood-propeller manufacture.

8. *Balsa.*—This is a tropical tree that is found only in a few places in the Philippines. Balsa is light-gray in color and frequently stained with bluish streaks. The most characteristic feature of balsa is its lightness. It is soft, smooth, brittle, and very easily worked. It is used only where strength is not a factor, such as for streamlining forms, fairing strips and for aircraft model construction. It can be used as the core for plywood.

STRENGTH CHARACTERISTICS OF WOOD

Philippine climate hardly varies and tropical trees do not undergo the rigid seasonal growth cycle experienced by trees growing in temperate countries so that Philippine woods lack the distinct yearly growth rings that is characteristic of wood in colder lands. On the other hand, Philippine woods are generally porous. There are some nonporous woods, like palosapis and balsa, which show no distinct pores or vessels. In the porous woods, the pores are distinctly visible and are characterized by the presence of dark amber-colored gum or a high amount of resin.

Tropical woods also have a rather irregular flow of the grain lines which gives peculiar intermeshed or intercrossing grains—a factor that makes the wood often hard to split. It is this intermeshing of the wood grains that causes the appearance of rough hairy strips on the wood surface when sawed into thin boards.

On account of the intermeshed character of the wood grains, tropical woods have a relatively high shear strength parallel or perpendicular to the characteristic intermeshing of the grains. While wood cut from young timber generally shows smooth grain flow, wood cut from aged timber is intermeshed. The irregular grain slopes make it sometimes difficult to procure long specimens of wood.

Wood for aircraft construction requires the closest inspection. Care must be taken in the selection so that the wood should be free as much as possible from any natural defects as compression failures, cracks, knots, decays and rots, etc. These defects can usually be recognized by the natural appearance of the stock and little experience is required to be able to make the selection satisfactory.

Since the grains in tropical woods tend to be knotty specially those cut from aged timber, it becomes increasingly difficult to determine the grain slope. Where the grains could be distinguished an average grain slope of from 1 to 12 up to 1 to 14 has to be chosen from the stock for the construction.

Other physical qualities of the wood that are of importance and which must be properly tested and checked before the material is finally chosen for use are specific gravity and moisture content. These qualities cause variations in the properties of the same species as well as of different species of wood.

Specific gravity.—Specific gravity or weight per unit volume rather than mechanical test is the best single criterion of the strength of wood. This weight is taken after the wood has been completely seasoned and ready for use. Determination of density and careful consideration of any defects, such as knots, cross grain, decay, etc., are now largely used as means of selecting airplane woods. Region of growth has some influence on the selection as the same wood from different regions may tend to have different densities. Generally, woods from the southern regions of the Philippines are lighter than those from the north and woods from the lowlands are somewhat heavier than those of the uplands and mountains.

Most Philippine woods are of the heavier type and tend to have a rich content of gum or resinous material. Of the few selected types suitable for aircraft construction, the specific weight of the final wood material averages between 0.5 to 0.6 gm/cm^3.

Specific gravity is generally calculated as follows:

$$\text{Specific gravity} = \frac{W}{V}$$

Where W = the weight of the specimen in the right moisture composition.
V = the volume of the specimen.

Moisture content.—Moisture is contained in saturated wood as free water within the cell cavities and as hygroscopic moisture within the cell walls. The free or excess water has no effect as such on volume or strength; however, after it has been drawn off and the water begins to come from the cell walls, the wood shrinks and at the same time increases rapidly in strength of load-bearing properties.

Toughness or shock resistance, being dependent upon both strength and pliability, sometimes actually decreases as the wood dries; dry wood will not bend as far as green wood. In drying, internal stresses are set up which tend to cause checks and other defects. The more the wood is dried, the greater is the tendency of these defects to develop.

The moisture content of the wood can be checked by using the standard procedure of weighing test specimen of the wood and drying it in an oven at 103 ± 2° until approximately constant weight is attained. After drying, the sample is weighed immediately.

Moisture content is calculated as follows:

$$M = \frac{Wo - W}{W} \times 100 \text{ (per cent)}$$

Where M = the moisture content in per cent.
Wo = the initial weight.
W = the final weight.

Shrinkage.—Shrinkage occurs when wood dries and this is stopped only at a point where the right moisture content is attained. Shrinkage is marked along the cross-sectional width of the wood. Along the longitudinal section there is practically no shrinkage. Shrinkage in the airframe wood must be avoided, since this tends to wrap the wood and may cause internal stresses and misalign the structure. It is highly important therefore that wood selected for aircraft use must be properly seasoned and that it should retain its form rather than change its size or shape as a result of shrinkage.

Table 1 lists the strength characteristics of Philippine woods suitable for use in light-aircraft construction.

TABLE 1.—*Strength characteristics of Philippine woods.* *

Name of wood	Specific weight		Bending strength		Tensile strength	Compression strength	Shear strength parallel to grain
	Ave.	Min.	Ave.	Min.			
	gm/cm^3	gm/cm^3	Kg/cm^2	Kg/cm^2	Kg/cm^2	Kg/cm^2	Kg/cm^2
Mayapis	0.565	0.500	850	635	950	350	70
Tangile	0.650	0.600	961	748	1,200	360	80
White lauan	0.525	0.480	650	500	720	250	55
Red lauan	0.616	0.520	760	600	825	300	65
Kalantas	0.460	0.375	650	520	720	270	58
Manggachapui	0.650	0.620	1,220	1,000	1,550	500	125
Balsa	0.150	0.120	180	96	238	52	------

Name of wood	Minimum modulus of elasticity	Strength **	Moisture content	Average grain slope	Availability	Workability	Cost per Bd. ft.
	Kg/cm^2		Per cent				
Mayapis	88,000	$1,505 \times 10^4$	12–14	1 in 13	Unlimited	Good	0.31
Tangile	133,000	$1,480 \times 10^4$	do	do	do	do	0.33
White lauan	98,000	$1,240 \times 10^4$	do	do	do	do	0.30
Red lauan	96,000	$1,216 \times 10^3$	do	do	do	do	0.35
Kalantas	94,000	$1,445 \times 10^4$	do	do	Limited	do	0.35
Manggachapui	120,000	$1,875 \times 10^4$	do	1–15	do	do	0.40
Balsa	26,000	$1,190 \times 10^3$	10–12	None	do	------	------

* Selected from seasoned straight-grain stock.
** Bending to weight ratio.

STRUCTURAL STRENGTH OF AIRCRAFT WOOD COMPONENTS

It is not sufficient to know the strength characteristics of the wood elements used in the construction under certain moisture condition. It becomes necessary sometimes to establish allowable stresses in designing structures to be statically tested as complete structures. Complete structures in aircraft include wing panels, center sections, fuselage, control surfaces, stabilizer, or other parts individually or in combination.

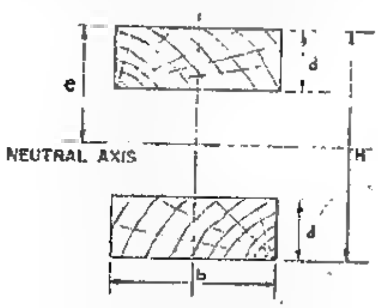


Fig. 1. Symmetrical spar section.

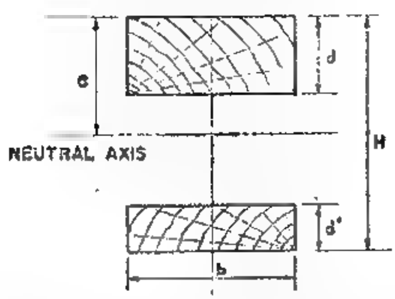


Fig. 2. Asymmetrical spar section.

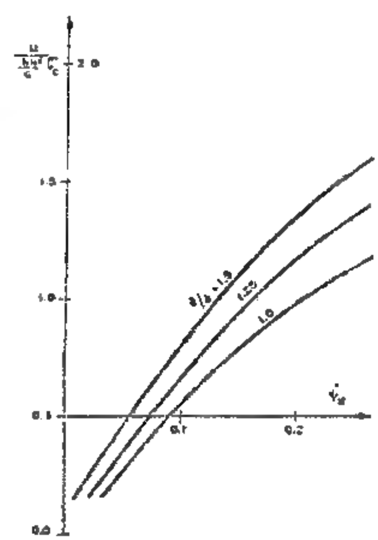


Fig. 3. Graph for determining spar dimensions of d'/H for varied values of d d'.

The static testing of complete structural components to determine the strength of the structure is done usually under conditions simulating as much as possible actual flight-loading conditions. In this respect a suitable safety factor ranging from 1.5 to 1.8—depending on the primary function of the part—is incorporated during the design to cover up for any unforseen weakness in the construction or for conservatively assumed design-loading conditions.[1]

[1] Design-loading conditions and actual structural test procedures are beyond the scope of this paper. Extensive data on these may be obtained from some of the references listed.

During the preliminary design stage it is sometimes necessary to assign dimensional values to certain primary structural parts. A useful method for determining design parameters for spar sections can be solved as follows: (Figs. 1, 2, and 3)

Given the strength characteristics of wood, the ultimate allowable stress in bending for a symmetrical spar section can be determined from the equation:

$$\sigma_A = \sigma_c \cdot \frac{b.d(H-d)}{I/c} + (\sigma_T - \sigma_c)\cdot\frac{b.d^2}{6I/c}$$

Where:

σ_A = Bending stress (Allowable)
σ_c = Compressive stress
σ_T = Tensile stress
I = Moment of inertia of spar
e = Distance from neutral axis to the outermost periphery of the section
d, b and H are dimensions of the spar section.

The ultimate bending moment for the section is given by:

$$M \text{ (Ultimate)} = \sigma_c . b . d(H-d) + (\sigma_T - \sigma_c)\ \frac{b . d^2}{6}$$

The actual design stress is:

$$\sigma_D = \frac{M_D . e}{I},$$

Where:

M_D = Design bending moment

The factor of safety will be determined from the ratio:

$$\text{F. S.} = \frac{\sigma_A \text{ (allowable)}}{\sigma_D} \geqq 1.5 + 1.8$$

The ultimate moment for an asymmetrical spar section of wood can be determined by:

$$M \text{ (Ultimate)} = \sigma_c . b . d\left(H - \frac{d + d'}{2}\right) + \left(\sigma_T - \frac{d}{d'}\sigma_c\right) \cdot \frac{b . d'^2}{6}$$

In stressing the spar section the values of H and b are usually given. The above equation can be transformed to a dimensionless form through division by:

$\frac{b . H^2}{6}\sigma_c$; if we equate $\delta = d/H$ and $\delta' = d'/H$, then

$$\frac{M}{\frac{b . H^2}{6}\sigma_c} = 3\delta(2 - \delta - \delta') + \left(\frac{\sigma_T}{\sigma_c} - \frac{\delta}{\delta'}\right)\delta'^2$$

The following figure gives for $\sigma_T/\sigma_c = 2$, and for varied values of d/d', the relationship for any given value of $\frac{M\sigma_c}{b.H^2/6}$ to enable one to determine the spar section dimensions out of Fig. 5.

APPLICATION OF WOOD AND PLYWOOD IN AIRCRAFT CONSTRUCTION

In the Institute of Science and Technology, the woods mentioned in the foregoing found extensive application in the actual construction of four different types of prototype light aircraft. Excepting for certain metal accessories, the aircraft airframe structures were built entirely of local woods and plywood.

Plywood of standard aircraft grade has not yet been made available from local manufacturers owing to the unusually high requirements in quality of the product and the very limited demand for such material. Ranging from 0.6 to 3 mm in thickness in the 3-ply form, it is generally thin, and thus local manufacturers have been wary to meet the desired specifications.

However, at our request, one company produced plywood with all three plys made either of lauan or of tañgile. The average thickness of the manufactured plywood ranged from 2 to 2.2 mm. Another special plywood was also manufactured with the outer grains set at 45° but with a thickness of 3 mm. These types of plywood were used in the XL–17 "Musang" prototype light aircraft trainer described below. The plywood was applied as stress skin construction cover for the whole aircraft airframe. Part of the covering was done with the diagonally-set-grain plywood—specially where pronounced bends were present in the structure as in the wing leading-edge portion, the nose portion of the control surface, and along the corners of the fuselage structure. The box construction main spar had plywood webs. Fuselage flooring was of 5 mm thick plywood; and whenever gussets were necessary plywood was used for reinforcements. Application of the plywood was by simple gluing and nailing.

For joining plywood panels together, lap, butt and scarf methods were used wherever applicable. The practice had been to make scarf joints directly on solid or laminated beam flanges and on relatively large wood members taking a plywood taper of 1:2.

Aircraft plywood panel sizes generally are dependent on the magnitude of the design stresses. For the thicker gauge of plywood used, the average 32 cm distance between the ribs in the XL–17 wings was much less than that otherwise would be required for a thinner plywood. Whenever cutouts were made in the skin, as for windows, inspection holes, brackets and

fittings' positions or other purposes, a doubler was glued around the cutout to reinforce it.

For shear webs the plywood was laid with the outside grain set diagonally about 45°. In this way the shear web would carry appreciably higher buckling and ultimate loads, because plywood is much stiffer in bending in the direction of the face grain and offers greater resistance to buckling if laid with the face grain across the direction of the buckles. The practice is supported by findings of an investigation on shear strength characteristics of wet and dry plywood. (Table 2)

TABLE 2.—*Shear strength characteristics of tangile and lauan plywood (3 ply).*

Position	Dry		Wet	
	Min.	Ave.	Min.	Ave.
	Kg/cm^2	Kg/cm^2	Kg/cm^2	Kg/cm^2
a. Outside ply perpendicular at 90°	90	120	60	90
b. Outside ply diagonal at 45°	120	145	95	120
c. Outside ply parallel at 0°	80	110	58	80

As the thickness of the plywood used was generally more than that actually called for in the design, an appreciable increase in the structural overall weight which amounted to about 8 to 10 per cent more than the original weight estimate was experienced. The weight of the 3-ply plywood panel ranged from 1.3 to 1.8 kg per square meter area.

In the manufacture of plywood for aircraft very much depends on the producer's care in following the specifications required in the use of the glues. This is to prevent any buckling or warping of the material after long exposure to weather. It had been observed that sometimes plywood which had been tested in the laboratory to give good gluing qualities still warped after some time on account of poor glue used and uneven mixing or uneven spreading of the glue.

The main objective in using wood for aircraft structural airframe construction is to maintain the best workmanship following the standards and tolerances required for aircraft material airworthiness. The same degree of workmanship usual to other woodworking industries, as smooth cutting and accurate fitting of the joints or splices, should be maintained. Extreme care is necessary to manufacture the various wood parts owing to the rigid design requirements limits of weight and strength.

In aircraft, wood parts are thin and joints are more frequently reinforced with stiffeners, braces and plywood webs. Where bolts and fittings are used, the holes must have accurate diameters and must have smooth surfaces for the bolts to bear against. Drilling is best accomplished by special high-speed bits that are so designed and operated as to prevent the splitting of the wood.

The four prototype light aircraft designed and constructed by the Institute of Science and Technology, in which wood and plywood were used, are described briefly as follows:

XL–14 MAYA (1951–52)

This was a three-seater experimental monoplane suitable for agricultural uses, general utility and observation.

Wings.—High-wing strut-braced monoplane. Center-section integral with fuselage cabin section. Outer wings braced by veestruts. Structure consisted of two parallel solid lauan wood spars, wood ribs, "Wobex" (woven bamboo) leading-edge reinforcement and fabric covering. Slotted flaps and ailerons. Total wing area was 16 sq. m.

Fuselage.—Semi-monocoque structure with wood frames and stringers and "Wobex" (woven bamboo) outer skin covering.

Tail unit.—Strut-braced tailplane with end-plate fins and rudders. All-wood construction with fabric covering.

XL–10B BALANG (1953–54)

This was a one-seater secondary type of glider which had been converted to accommodate an auxiliary power plant in order to allow it to make powered take-offs and a limited powered flight. Materials of construction were mayapis and tangile plywood, and the overall covering was cotton fabric.

Wings.—Built up of two parallel solid wood spars braced by V-form profile metal tube struts. Ribs were of the normal truss-type construction of wood capstrips and fish paper gussets for reinforcements. Ailerons had solid wood spars.

Fuselage.—Two-piece type and consisted of a forward section incorporating the pilot's seat in a reinforced lower skid hull, the upper bracing frame for the wing attachment, and a rear detachable fuselage truss. All materials of construction were mayapis wood and plywood.

XL–15 TAGAK (1954-55)

This was a general purpose, light-utility, aero-medical aircraft built to accommodate four persons or to carry two litter-patients with the pilot and an attendant.

Wing.—High monoplane type wing of semi-cantilever construction. It had three sections—a main center wing section built as an integral part of the cabin, and two outer wing section panels bolted at four points. The main spar had laminated tangile "wood flanges of box-section" reinforced with plywood webs. An auxiliary rear spar was provided for stiffening and for the attachment of ailerons and flaps. A diagonal wing spar was also provided for torsional rigidity and in taking wing chordwise loads.

Both spars were held by truss-type cantilever-type ribs with gussets and plywood webs. The overall material of construction was wood. The wing covering was of composite construction consisting of a torsional nose covering of plywood, a leading edge of "Wobex," and an overall fabric outer-wrapping.

Fuselage.—All-cabin type semi-monocoque construction with the rear fuselage section replaced by two booms which were attached to the wings. The fuselage structure was of reinforced wood, lauan stringers and frames and plywood and partly covered with "Wobex." Cabin flooring was of reinforced plywood.

Control surfaces.—The horizontal tail was attached to the two parallel-set rear tail booms. The fixed stabilizer was of wood–plywood construction. The upper surface was plywood-covered and the leading edge was "Wobex"-covered. The twin vertical fins were off wood–plywood construction and covered with "Wobex." The overall construction material used was wood spars and ribs with an outer skin of plywood and "Wobex" and an overall covering of fabric.

XL–17 MUSANG (1955-56)

This was a light two-(side by side) seater monoplane with low cantilever wing and a tricycle landing-gear system. It was intended as a personal aircraft for sporting purposes and as a light primary trainer.

Wing.—The one-piece wing was built up of a symmetrical box-type section main spar of mayapis wood–plywood construction and an auxiliary rear spar for reinforcement and for the attachment of split-type flaps and slotted ailerons. Ribs were

of kalantas wood frames and plywood webs. The whole wing was plywood-covered with an outer fabric wrapping.

Fuselage.—The fuselage was built up of lauan bulkheads and frames, wood stringers, and overall plywood stress skin shell and then fabric-covered. Cabin floor was of plywood; so were the side-by-side seats which were of plywood-reinforced wood construction.

The horizontal tail was of cantilever construction with box-type wood spars and plywood webs. Ribs were of wood and plywood. The overall covering was plywood with an outer fabric wrapping.

The vertical fin was integral with the fuselage tail section framework and was plywood-covered. The vertical rudder framework was built up of a solid spar and truss-type wood ribs.

WOOD STRUCTURAL DESIGN TECHNIQUE

Spars.—Two types of beams were used throughout the design of the four prototype aircraft described above. The first was the single plain rectangular solid type as was used in the construction of the XL–10B glider spars and in the control surface spars of most of the other aircraft. This type is useful only where the wing loading is low. A modification of the rectangular solid type is the laminated solid lauan wood spars used in the XL–14 "Maya" aircraft because of the higher stresses on the wings. (Fig. 4)

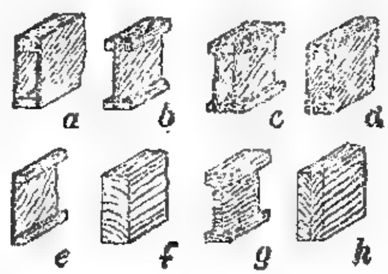


FIG. 4. Types of aircraft wood spar constructions used: *a*, box; *b*, "I"; *c*, double "I"; *d*, box with laminated flanges; *e*, "[" ; *f*, plain rectangular; *g*, routed; *h*, laminated rectangular.

Since the tension member is adversely affected by any type of defect in wood, it was always advisable to laminate all tension flanges in order to minimize the effect of small defects remaining hidden within a solid member of large cross-section.

The second type of spar was the solid flanged [-beam type used as the auxiliary spars in the XL–15 and XL–17 aircraft. In the main-spar construction of these aircraft the box-type section with laminated flanges was used. (Fig. 4)

In the [-beam, the webbed faced was used for the attachment of ribs but because unstable under high shear loading it was applied only for the auxiliary rear spar, the diagonal spar, and sometimes for control-surface spars.

Shear webs.—Throughout the design of main spars, the shear web of plywood was laid in the diagonal so that the outer plywood grain was at an angle of 45° to the direction of the shear load. In certain auxiliary spars the web was laid with the grain at 90° to the shear load direction. The diagonally set plywood web had the advantage of taking appreciably higher shear loads because it was stiffer in bending and buckling in the direction of the face grain.

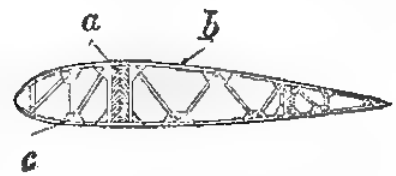


FIG. 5. Truss type rib used in the XL-14 MAYA. *a*, laminated main spar; *b*, wood cap strip; *c*, hard paper gusset.

Beam stiffeners.—In order to reinforce the spar shear-webs and provide spacers for the flanges, wood stiffeners were used internally in all-spar construction. They were usually placed at every rib location, so that the web would be stiffened sufficiently to resist the rib-assembly pressures.

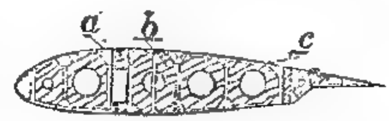


FIG. 6. Lightened plywood web type used in the XL-17 MUSANG. *a*, box-type main spar; *b*, plywood web; *c*, wood rib cap strip.

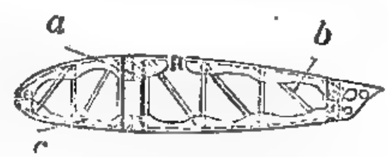


FIG. 7. Rib employing continuous gussets used in the XL-15 TAGAK. *a*, box-type spar; *b*, wood cap strip; *c*, plywood gusset.

Blockings.—Blockings were provided in spar roots where the strut bracing was to be attached to the wings. Where blockings were placed they were properly tapered in order to prevent too much stress concentration in the wood structure.

Ribs.—Ribs for the different prototype aircraft were designed according to the special purpose for which each was intended and varied between three general types:

a. The plywood web rib of the cantilever type where the rib frame was fully covered with plywood. This was used for high chordwise compression loads.

b. Rib with lightened plywood.

c. Truss-type ribs.

Frames and bulkheads.—In the all-wood type of airframe construction, frames and bulkheads for the attachment of plywood or "Wobex" covering were needed for stiffening the structure. Both solid and lamination wood-type bulkheads with plywood reinforcing gussets were used throughout the construction. Where large-size frames were used, as in the cabin portion of the fuselage, the solid and the laminated side-members were stiffened at the corners by wood blocks which were later trimmed. In the case of smaller bulkheads, as those needed in the booms of the XL–15 "Tagak" aircraft, they were cut from one-piece plywood.

Other uses.—Other uses for the plywood ranged from corner blocking of frames to stiffeners and included construction of wood-aircraft cabin fixture and accessories and propellers. Scale models were built of balsa wood. Shop jigs and special fixtures were also built of the scrap wood materials discarded from the chosen stock.

Gluing of the wood.—Tropical woods have good gluing characteristics. Glue was the main material used for the assembly of wood structural parts. The wood parts were first cleaned and properly smoothened by planing. Complete contact of the wood members over the entire joint area to be glued was made with a continuous filling of glue—free of air bubbles. The glue was of the right consistency and to this the proper amount of pressure was applied. Most glued joints were done with the use of clamps. The amount of pressure required varied according to the glue consistency—a lighter pressure was applied to lighter glues and more pressure applied to heavier or thicker glues, varying from 8 to 10 kg/cm^2 for kalantas up to 15 kg/cm^2 for manggachapui.

A commercially available water-resistant glue with the trade name of "Weldwood glue" was used throughout the various experimental aircraft construction. This was a synthetic resin glue of the urea formaldehyde base type adhesive which could be worked at normal room temperature between 80 to 90°F. and had good binding characteristics.

Pressing time for the glue generally was 8 to 10 hours but preferably it was kept often up to 20 to 30 hours depending on the nature of the gluing.

Protection of the wood and plywood.—Finishing of wooden aircraft parts and surfaces varied according to the degree of protection and the quality of the finish desired. In the con-

struction of the various prototype aircraft, the wood had to be given the necessary inside and outside surface protection with protective coatings to secure it from weather and sunlight and to prevent excessive swelling and shrinking caused by changes in its moisture content.

For the interior finish two to three coats of good quality wood varnish was used. For exterior finish two coats of clear lacquer varnish was used. In most cases, however, specially in the wings and control surfaces, fabric cloth was used to cover the surface after the initial lacquer varnish coating was applied. The cloth was first applied to the surface by the use of clear aircraft dope and then given a final coating of pigmented dope for finishing. Wood surfaces that had to be in contact with metal fittings or accessories was protected with the application of two coats of wood varnish. Bolts and screws were wet with varnish, zinc chromate primer or glue before they were placed in the wood structures.

REMARKS AND CONCLUSION

All the various aircraft prototype models have been subjected at one time or another to the direct effect of weather conditions. They have been subjected to rain and sunshine for long periods of time. In certain cases parts of the plywood structure were observed to warp. This can be attributed to poor gluing characteristics of the plywood when it was manufactured. Where the airframe had been properly protected with paint or varnish, weather effects can be said to affect it very slightly. Extensive actual functional and flight tests have demonstrated that the wood structure can take all loads arising from the operation of the aircraft and in points of strength have passed the necessary airworthiness tests. The wood structures have demonstrated high stiffness and good vibration absorbing characteristics under adverse loading conditions. Durability tests of the aircraft are, however, still continuing under actual operational conditions.

Where commercial grade plywood had been used in the flooring of the XL-15 "Tagak" aircraft it was observed after the rainy season to have warped and in some instances the outer ply had peeled off entirely. This was due to the fact that manufacturers sometimes have the practice of using extenders for the glue they use, and even if the product is branded as grade A, water-resistant, it may still warp a time owing

to poor gluing qualities. Incidentally, the plywood used in this particular aircraft was procured from the retail market and was the only material available at the time.

It must be mentioned in conclusion that we have enough good quality woods here in the Philippines that can be readily adapted for aircraft construction. There are sufficient raw materials to go into light aircraft and accessories manufacturing even in quantity production scale. But the technique in the manufacture of plywood of good aircraft quality still needs to be improved.

REFERENCES

1. Aircraft Woodwork Technical Manual 1–414. Wash., D.C. (1942).
2. ASTM Designation: D 805–52, adopted 1947; revised, 1952.
3. Civil Air Regulations. Part 3 and Manual—04. Wash., D.C. (1949).
4. Design of wood aircraft structures. ANC Bull. (June 18, 1944).
5. Leon, A. J. de. Aircraft design notes. (Unpublished).
6. Tamesis, Florencio, and Luis Aguilar. Important Commercial Timbers of the Philippines. DANR Bull. No. 2 (Manila, 1951).
7. Werkstoffkunde, V. Ing. Cl. Bohme. Berlin (1937).
8. Wood aircraft design and production. Aero Digest 49 (1945).
9. Zeitzchrift fur flugtecknik und mortorluftschiffart 19 (1933).

ILLUSTRATIONS

PLATE 1

FIG. 1. The XL-14 MAYA shown with complete wood airframe assembly. Portion of fuselage is covered with WOBEX (Woven bamboo experimental mat covering).

2. The XL-10B BALANG before final fabric covering of complete airframe.

3. The XL-15 TAGAK (rear section) showing detailed wood framework construction.

PLATE 2

FIG. 4. The XL-15 TAGAK in preliminary assembly stage, the fuselage covered with plywood, the tail boom with WOBEX and plywood; the semi-cantiliver is also of wood.

5. The XL-17 MUSANG with the wood bulkheads and stringers framework partially covered with plywood.

6. The XL-17 MUSANG in final assembly stage with plywood covering.

TEXT FIGURES

FIG. 1. Symmetrical spar section.

2. Asymmetrical spar section.

3. Graph for determining spar dimensions from the relationship of

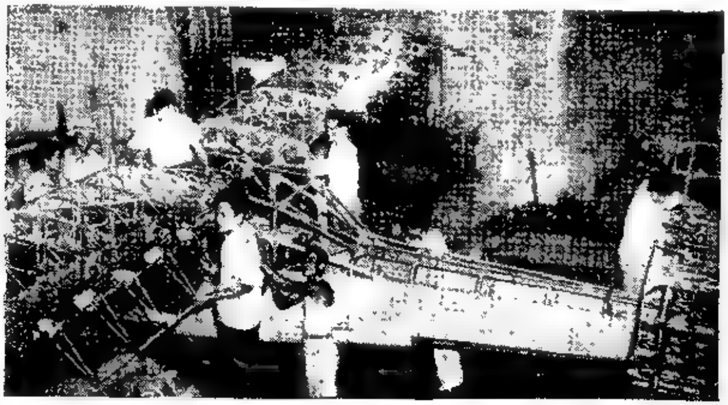
$$\frac{M}{b.H^{2.0}C/6} \text{ as function of } d'/H \text{ for varied values of } d/d'.$$

4. Types of aircraft wood spar constructions used: *a*, box; *b*, "I"; *c*, double "I"; *d*, box with laminated flanges; *e*, "[" ; *f*, plain rectangular; *g*, routed; *h*, laminated rectangular.

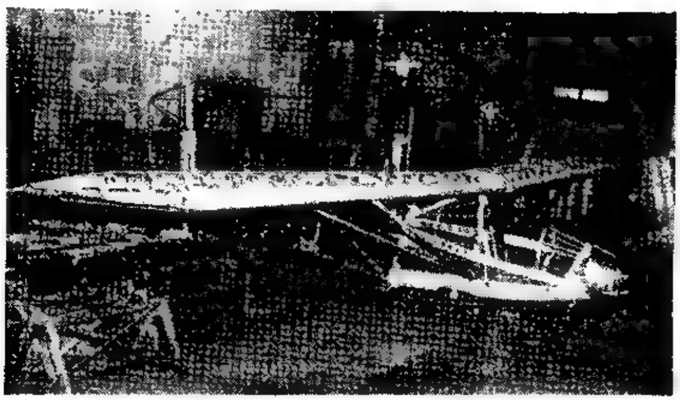
5. Truss type rib used in the XL-14 MAYA. *a*, laminated main spar; *b*, wood cap strip; *c*, hard paper gusset.

6. Lightened plywood web type used in the XL-17 MUSANG. *a*, box-type main spar; *b*, plywood web; *c*, wood rib cap strip.

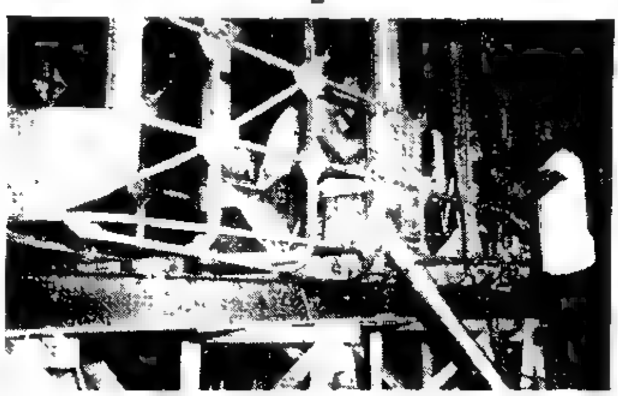
7. Rib employing continuous gussets used in the XL-15 TAGAK. *a*, box-type spar; *b*, wood cap strip; *c*, plywood gusset.



1

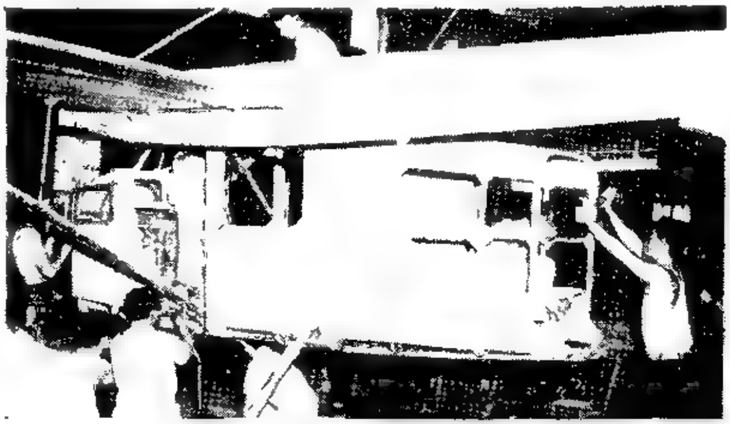


2

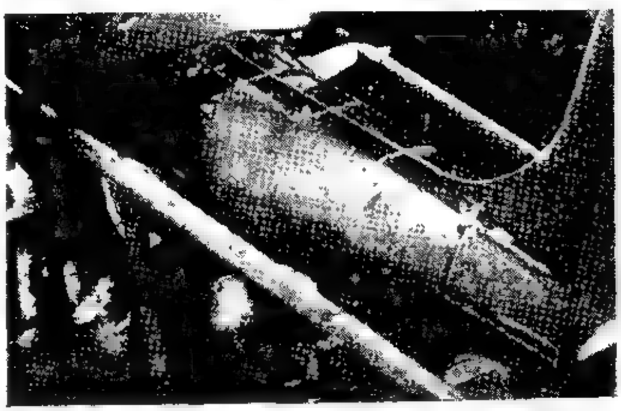


3

PLATE 1.



4



5

6

PLATE 2.

STUDIES ON PARAGONIMIASIS, VIII *

ON THE EXCYSTATION OF PARAGONIMUS METACERCARIÆ **

By Mariano G. Yogore, Jr., Benjamin D. Cabrera, Trinita P. Araullo and Ernesto F. Cabalteja

Department of Parasitology, Institute of Hygiene
University of the Philippines

ONE PLATE AND THREE TEXT FIGURES

For the study of the morphology of the larval stages of *Paragonimus* in the Philippines,[1] we obtained the excysted metacercariæ by placing the encysted forms in physiologic salt solution and holding them at 40°C in a water bath. This procedure was suggested to us by Dr. Muneo Yokogawa who had been using this method for obtaining excysted metacercariæ for *in vitro* cultivation of *P. westermani* at the National Institute of Public Health in Tokyo, Japan.

Since obtaining the first excysted metacercariæ in our own laboratory, we have realized that certain aspects of the behavior of *Paragonimus* in the definitive host could be investigated with these forms as the starting point. In preliminary work on such a problem, we needed a considerable number of the excysted forms on several occasions. We were thus led to a consideration of the process of excystation and of the factors that influence it in order that we could obtain the excysted metacercariæ at the right time and in sufficient numbers for our work.

Aside from the practical considerations arising from our own needs in the laboratory, our interest was further stimulated by the fact that we could not find in the limited literature available to us any detailed studies on the excystation of *Paragonimus* metacercariæ. We have endeavored, therefore, to gain some understanding of this biological phenomenon by studying

* Studies supported by grants-in-aid from the research fund of the University of the Philippines.

** Presented at the Ninth Pacific Science Congress held in Bangkok, Thailand in November–December, 1957.

[1] Yogore, M. G., Jr., G. A. Noble, and B. D. Cabrera. Philip. Jour. Sci. 86 (1957) 47–69.

it and this paper is a presentation of some observations that we have made.

MATERIALS AND METHODS

The *Paragonimus* encysted metacercariæ used in these experiments were obtained from naturally infected *Parathelphusa* (*Barythelphusa*) *grapsoides*, the crab intermediate host [2] of the fluke in the Philippines. These crabs had been collected from fresh-water mountain streams in Casiguran, Sorsogon—one of the areas in this country where paragonimiasis is known to be endemic.[3] These crabs were kept alive in aquaria in the laboratory. When the metacercariæ were needed, the carapace of the crab was lifted off and the metacercariæ were immediately teased from the tissues (heart, pericardium, and body muscles) and transferred to a Petri dish with physiological salt solution by pipette.

Microscopic observation of excystation.—A slide (7.5 cm long, 2.5 cm wide and 6 mm thick) with a flat-bottomed well 15 mm in diameter and 3 mm deep was used in this study. About 20 freshly obtained metacercariæ were placed by pipette in physiologic salt solution in the well. A cover slip was then applied over the well in such a manner that no air bubbles, which would obscure observation, were caught in the preparation.

The slide was placed on a C. S. & E. Co. (Chicago, U. S. A.) Type 7 warm stage so that the well was over the hole at the center of the warm stage. The warm stage had been adjusted beforehand to keep a temperature of 40°C. Slide and warm stage were then mounted on a microscope and observations were made at 100x magnification.

Timed observations of excystation.—The same slide-warm stage arrangement as used above was employed. This was modified only in that the 30 metacercariæ used in each run were grouped together in the slide so that all of them could be observed in one dissecting microscopic field at 20x magnification. The isotonic salt solution used as excystation medium was at pH 9.

At the start of each run, a sketch was made of the position of all the metacercariæ so that each could be followed without

[2] Yogore, M. G., Jr. Philip. Jour. Sci. 86 (1957) 37–44.

[3] Yogore, M. G., Jr., B. D. Cabrera, and G. A. Noble. Philip. Jour. Sci. 87 (1958) 197–215.

difficulty during the period of observation. Each run was timed from the instant the slide was placed on the warm stage and the following time intervals were then recorded for each metacercaria that completed excystation during a 2-hour period:

(*a*) Time from the start of the run until rupture in the cyst wall (which we will refer to as "I-Time" in this paper);
(*b*) Time from the moment of rupture in the cyst wall to the instant of complete escape of the larva from the cyst ("E-Time"); and
(*c*) Total time ("T-Time") for (*a*) plus (*b*).

Three runs using freshly obtained metacercariæ ("M-Fresh" group) were performed. In addition, two runs were made with metacercariæ which had been stored in saline solution at refrigerator temperature (5° to 6°C) for 24 hours ("M-24 Hrs." group) and also two runs of metacercariæ similarly stored for 8 weeks ("M-8 Wks." group). The "M-24 Hrs." and "M-8 Wks." metacercariæ were run because preliminary trials had shown that *Paragonimus* encysted metacercariæ could be stored for several weeks in the manner described without apparently affecting the ability of these metacercariæ to undergo excystation when eventually placed at 40°C.

Observations on the effects of pH and temperature on excystation.—Only freshly obtained metacercariæ were used in each run in this series. Fifty metacercariæ were used in each run, the metacercariæ being placed in flat-bottomed vials (5 to a vial). Observations were made at the end of each hour for 8 hours after the start of the run with the reading of the number of metacercariæ having undergone excystation being made by examining each vial under a dissecting microscope at 20x magnification.

Isotonic salt solutions were used in all the runs, the solutions being at pH 9, pH 7, pH 5, or pH 3 as checked in a Beckman pH meter. Isotonicity of solution was checked by effect on human red blood cells.

Three temperature conditions were studied: (*1*) at 40°C in a water bath, (*2*) at room temperature of 31° to 32°C, and (*3*) at air-conditioned room temperature of 22° to 23°C.

A total of 32 runs were made. In 20, the same pH was used throughout the 8 hours of observation; in the other 12, pH 3 was used for the first 3 hours and then the medium was changed with that of a solution at pH 9 or pH 7.

RESULTS

Description of excystation.—In observing a number of encysted metacercariæ in the slide-warm stage arrangement, it is oftentimes possible to spot those which are about to undergo excystation. The larva in such a cyst continuously changes its outline as different portions of it contract and relax causing one part or other of its body to retract from the cyst wall (Plate 1, *a*). Moreover, the contractions also result in some changes of shape and dimension of some organs such as the intestinal cæca and excretory bladder. Activity may sometimes be so marked as to cause an appreciable rotation of the larva within the cyst. Sometimes a slight dent which may indicate the site of eventual rupture may be observed on the inner surface of the cyst wall against which the anterior end of the larva has just pressed.

The actual breaching of the cyst wall occurs very suddenly. The anterior end of the larva explodes out through a small rent in the cyst wall (Plate 1, *b*). Then follows a period in which the larva actively struggles to deliver the broader portions of its body through the narrow opening it has just created. Contraction waves, apparently occurring as rings, are initiated at the anterior end of the body and pass posteriorly. As a particular segment of the body is involved in the contraction, this segment lengthens and attenuates while the segment over which the contraction ring has just passed relaxes and assumes its normal dimensions. Almost immediately after a contraction ring has reached the posterior end of the body, a new one is initiated at the anterior end. The segment of the larval body filling the narrow opening remains constricted and as the ring involves it, a little more of the body is "milked" out as this segment attenuates and lengthens (Plate 1, *c–e*).

During the struggle of the organism to escape its prison, especially when about half of its body is already out and the relatively broader posterior half has to pass through the opening, much of the blackish contents of the excretory bladder is discharged through the excretory pore, the discharge taking place in spurts as the contraction ring passes through the posterior half of the body (Plate 1, *e*). At this stage, a larva may attach itself to the substratum and move about, dragging its cyst along. The larva may then detach itself completely from the cyst wall, leaving the latter with a rent with out-

turned lips to show its successful excystation and the discharged contents of its excretory bladder as testimony of its struggle for freedom (Plate 1, *f* and *g*).

Time sequence of excystation.—Out of 90 "M–Fresh" metacercariæ observed in this series, 27 (30 per cent) completed excystation within the 2-hour observation period while 49 (81.7 per cent) of 60 "M–24 Hrs." and 44 (73.3 per cent) of 60 "M–8 Wks." metacercariæ did so. The timed observations on the excystation of the "M–Fresh" metacercariæ are given in Table 1, those of the "M–24 Hrs." metacercariæ are shown in Table 2 and those of the "M–8 Wks." metacercariæ in Table 3.

TABLE 1.—*Two-hour observation on the excystation of "M–Fresh" Paragonimus metacercariæ in isotonic salt solution, pH 9, at 40°C.*

Metacercaria	"I–Time"	"E–Time"	"T–Time"
Number	*Minutes*	*Minutes*	*Minutes*
1	12	12	24
2	22	5	27
3	22	11	33
4	33	1	34
5	40	18	58
6	41	32	73
7	48	13	61
8	50	1	51
9	51	20	71
10	52	30	82
11	53	1	54
12	53	6	59
13	55	49	104
14	56	11	67
15	56	5	61
16	60	2	62
17	61	21	82
18	66	14	80
19	67	1	68
20	70	2	72
21	70	24	94
22	72	1	73
23	81	7	88
24	81	15	96
25	87	8	95
26	93	12	105
27	104	2	106

It might be expected that a very active larva inside the cyst wall which takes a minimum of time to rupture the wall will also be able to rapidly escape from confinement while a less active one taking a longer "I–Time" will also have a longer "E–Time." In other words, a straight line relationship between "I–Time" and "E–Time" of excystation might be expected. The wide scatter of points in the scattergram presented as Fig. 1, in which the "I–Time" of each excysted metacercaria in Tables 1, 2, and 3 are plotted against its "E–Time," gives no indication of the expected relationship.

TABLE 2.—*Two-hour observation on the excystation of "M–24 Hrs." Paragonimus metacercariæ in isotonic salt solution, pH 9, at 40°C.*

Metacercaria	"I–Time"	"E–Time"	"T–Time"
Number	*Minutes*	*Minutes*	*Minutes*
1	4	15	19
2	5	9	14
3	5	13	18
4	7	20	27
5	8	1	9
6	9	8	17
7	9	11	20
8	10	21	31
9	10	20	30
10	12	4	16
11	12	21	33
12	12	2	14
13	13	3	16
14	13	35	48
15	13	44	57
16	14	6	20
17	15	37	52
18	16	51	67
19	17	5	22
20	17	6	23
21	18	7	25
22	18	43	61
23	20	3	23
24	20	4	24
25	21	8	29
26	22	27	49
27	23	2	25
28	23	71	94
29	24	46	70
30	24	33	57
31	26	23	49
32	26	18	44
33	27	33	60
34	27	18	45
35	27	44	71
36	30	24	54
37	31	4	35
38	31	28	59
39	34	42	76
40	35	41	76
41	35	46	81
42	36	83	119
43	44	1	45
44	44	4	48
45	48	13	61
46	53	5	58
47	64	54	118
48	68	3	71
49	70	2	72

For comparison, the mean "I–Time," "E–Time" and "T–Time" and their standard deviations for the "M–Fresh," "M–24 Hrs.," and "M–8 Wks." excysted metacercariæ are given in Table 4.

While there was considerable variation, the average "M–Fresh" metacercaria needed 70 minutes in which to complete excystation, with almost 60 minutes being for "I–Time" and only 12 minutes for "E–Time."

It is interesting to note that there was no significant difference in the time sequence of excystation between the metacercariæ which had been stored at refrigerator temperature for only 24 hours and those which had been stored for 8 weeks;

TABLE 3.—*Two-hour observation on the excystation of "M–8 Wks." Paragonimus metacercariæ in isotonic salt solution, pH 9, at 40°C.*

Metacercaria	"I–Time"	"E–Time"	"T–Time"
Number	*Minutes*	*Minutes*	*Minutes*
1	9	6	15
2	14	8	17
3	14	11	25
4	14	13	27
5	15	16	31
6	15	11	26
7	16	1	17
8	16	16	32
9	17	11	28
10	17	4	21
11	18	15	33
12	18	24	42
13	19	34	63
14	19	12	81
15	20	9	29
16	20	36	56
17	21	26	47
18	22	4	25
19	22	27	49
20	25	17	42
21	28	3	29
22	28	44	70
23	28	13	41
24	29	21	50
25	32	7	39
26	33	44	77
27	34	23	57
28	34	1	35
29	34	25	59
30	35	21	56
31	36	13	49
32	36	4	40
33	36	6	42
34	37	49	86
35	37	18	55
36	37	17	54
37	37	26	63
38	42	22	64
39	47	48	95
40	50	18	58
41	54	11	65
42	59	34	93
43	64	36	100
44	65	55	120

TABLE 4.—*Comparison of the "I-Time," "E-Time" and "T-Time" of the "M–Fresh," "M–24 Hrs." and "M–8 Wks." excysted metacercariæ (minutes).*

	"I–Time"		"E–Time"		"T Time"	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
"M Fresh" group	57.6	±21.6	12.0	±11.6	70.0	±28.2
"M-24 Hours" group	24.3	±15.8	21.7	±19.5	45.9	±26.3
"M-8Wks." group	29.5	±13.8	19.4	±13.8	48.9	±23.7

moreover, the emerged larvæ from both groups of stored metacercariæ were apparently as healthy and viable as those coming from the freshly obtained encysted forms. There is, however, a pronounced difference in the time sequence of excystation of

TABLE 3.—*Two-hour observation on the excystation of "M-8 Wks." Paragonimus metacercariæ in isotonic salt solution, pH 9, at 40°C.*

Metacercaria	"I-Time"	"E-Time"	"T-Time"
Number	*Minutes*	*Minutes*	*Minutes*
1	9	6	15
2	14	3	17
3	14	11	25
4	14	13	27
5	15	16	31
6	15	11	26
7	16	1	17
8	16	16	32
9	17	11	28
10	17	4	21
11	18	15	33
12	18	24	42
13	19	34	53
14	19	12	31
15	20	9	29
16	20	36	56
17	21	26	47
18	22	4	26
19	22	27	49
20	25	17	42
21	26	3	29
22	26	44	70
23	28	13	41
24	29	21	50
25	32	7	39
26	33	44	77
27	34	23	57
28	34	1	35
29	34	25	59
30	35	21	56
31	36	13	49
32	36	4	40
33	36	6	42
34	37	49	86
35	37	18	55
36	37	17	54
37	37	26	63
38	42	22	64
39	47	48	95
40	50	18	68
41	54	11	65
42	59	34	93
43	64	36	100
44	65	55	120

TABLE 4.—*Comparison of the "I-Time," "E-Time" and "T-Time" of the "M-Fresh," "M-24 Hrs." and "M-8 Wks." excysted metacercariæ (minutes).*

	"I-Time"		"E-Time"		"T-Time"	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
"M-Fresh" group	57.6	±21.6	12.0	±11.6	70.0	±28.2
"M-24 Hours" group	24.3	±15.8	21.7	±19.5	45.9	±26.3
"M-8 Wks." group	29.5	±13.8	19.4	±13.8	48.9	±23.7

moreover, the emerged larvæ from both groups of stored metacercariæ were apparently as healthy and viable as those coming from the freshly obtained encysted forms. There is, however, a pronounced difference in the time sequence of excystation of

the "M–Fresh" metacercariæ from that of both groups of stored metacercariæ. The "I–Time" observed for the stored metacercariæ was on the average shorter by more than 20 minutes than that of the "M–Fresh" metacercariæ. Statistical treatment shows that the differences observed were 3.6 times and 3.2 times the standard error of the difference for the "M–24 Hrs." and "M–8 Wks." metacercariæ respectively.

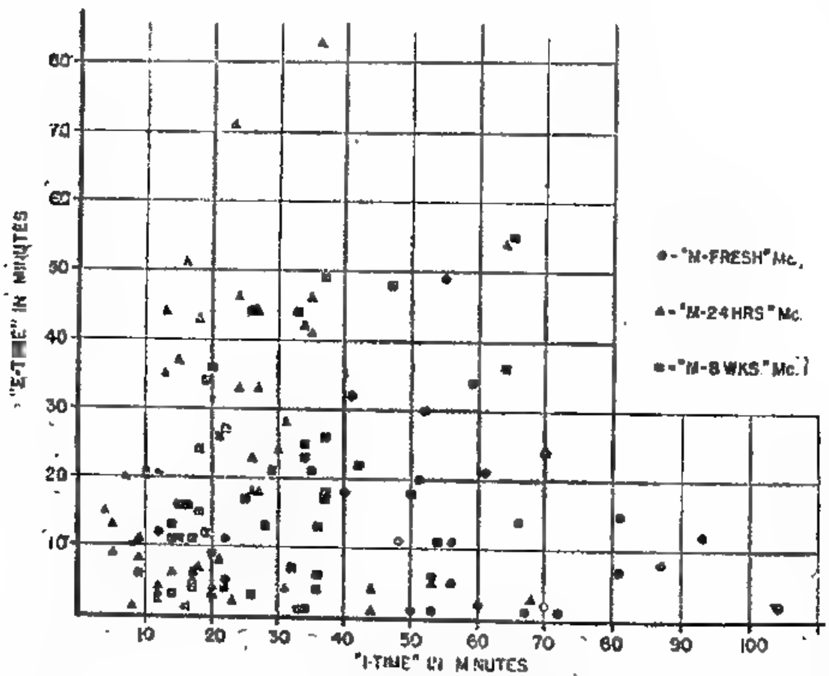


FIG. 1. "I–Time" plotted against "E–Time" for the excysted metacercariæ in Tables 1, 2, and 3.

The shortening of "T–Time" for the stored metacercariæ is the result of a marked cut in the "I–Time" in the excystation of these larvæ. The mean "I–Time" of the "M–24 Hrs." and of the "M–8 Wks." larvæ were 33 and 28 minutes shorter, respectively, than that of the "M–Fresh" metacercariæ. These differences are 9.6 and 6.0 times, respectively, the standard error of the difference.

On the other hand, the "E–Time" of the stored metacercariæ was longer than that of the "M–Fresh" metacercariæ by 9 and 7 minutes, respectively, for the "M–24 Hrs." and "M–8 Wks." groups. These differences are 2.7 and 2.4 times the standard error of the difference, respectively.

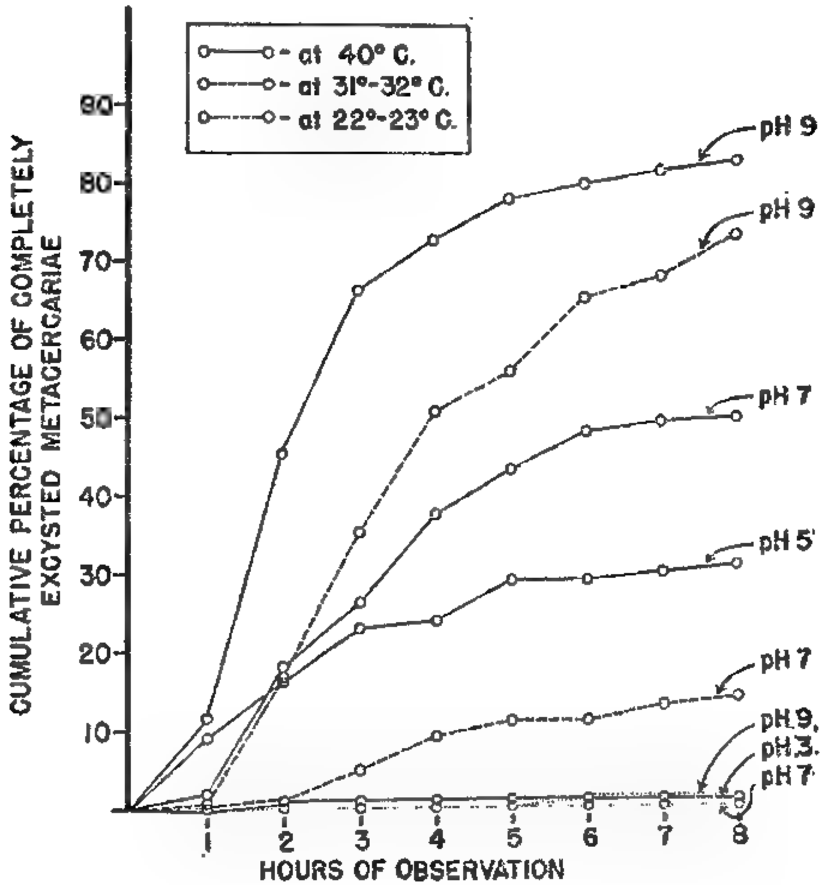


FIG. 2. Excystation of *Paragonimus* metacercariæ at different conditions of temperature and pH.

pH and temperature effects on excystation.—The results of each of the 32 runs made in this series in order to determine the effects of different conditions of temperature and pH on the excystation of *Paragonimus* metacercariæ are given in Table 5. These results are expressed in terms of the cumulative percentage of metacercariæ which completed excystation at the end of each hour for the 8 hours of observation.

The average curves for the runs made at the same temperature and pH conditions throughout the observation period are presented in Fig. 2.

TABLE 5.—*Excystation of Paragonimus metacercariæ at different conditions of temperature and pH.*

Temperature	pH	Runs†	Cumulative percentage of completely excysted metacercariæ at end of hour							
			1	2	3	4	5	6	7	8
Water bath at 40°C	9	1-A	12	46	64	74	82	86	88	88
		5-B	12	50	60	68	78	80	80	82
		9-C	10	48	74	76	78	78	82	82
		11-D	12	38	68	72	74	76	76	80
	7	2 A	4	32	44	58	64	72	72	74
		6-B	2	14	18	22	24	26	30	30
		13-D	0	8	18	32	42	46	46	48
	6	3 A	14	20	30	32	36	36	36	36
		7-B	4	12	16	16	22	22	24	26
	3	4-A	0	2	2	2	2	2	2	2
		8 B	0	0	0	0	0	0	0	0
	3→9††	10-C	0	0	0	X 70	86	92	92	96
		12-D	0	0	0	X 66	84	90	92	92
	3→7††	14-D	0	0	0	X 24	54	66	68	74
Air temp. at 31° to 32°C	9	15-E	0	12	26	36	44	58	64	68
		19-F	0	18	42	66	68	70	70	76
		23-G	2	20	38	50	56	68	70	76
	7	17-E	0	0	2	8	10	10	12	12
		21-F	0	2	8	10	12	12	14	16
	3→9††	16-E	0	0	0	X 10	40	54	64	70
		20 F	0	0	0	X 0	12	38	48	54
		24-G	0	0	0	X 0	10	30	44	46
	3→7††	18-E	0	0	0	X 2	8	12	20	28
		22 F	0	0	0	X 0	6	16	18	20
Air temp. at 22° to 23°C	9	25-H	0	0	0	0	0	2	2	2
		29-I	0	0	0	0	0	0	0	0
	7	27-H	0	0	0	0	0	0	0	0
		31-I	0	0	0	0	0	0	0	0
	3→9††	26-H	0	0	0	X 0	0	0	0	0
		30 I	0	0	0	X 0	0	0	0	0
	3→7††	28-H	0	0	0	X 0	0	0	0	0
		32-I	0	0	0	X 0	0	0	0	0

† Runs given the same letter were performed simultaneously.
†† X, indicates point where medium of different pH was used.

In four runs at 40°C and pH 9, excystation was relatively consistent with 80 per cent or more of the metacercariæ used completing the process at the end of 8 hours with the curve of excystation rising steeply at the 2nd to the 4th hour and tapering from the 5th to the 8th hour. At the same temperature, excystation at pH 3 was negligible while the total percentage of excysted metacercariæ at pH 7 and pH 5 was significantly lower than that at pH 9 with excystation at pH 5 significantly less than at pH 7.

At 31° to 32°C, the total percentage of excysted metacercariæ was significantly higher at pH 9 than at pH 7; however, the percentage of excysted metacercariæ at similar pH was significantly lower at this temperature than at 40°C.

At temperature 22° to 23°C, excystation was negligible or nil at pH 9 and pH 7.

The curves of 3 runs at 40°C in which the medium used was brought up to either pH 9 or pH 7 after an initial period of three hours incubation at pH 3, together with their controls which were run simultaneously, are seen in Fig. 3. Nearly identical curves were obtained for two runs in which the medium was changed from pH 3 to pH 9 after the 3rd hour of observation, with no excystation at pH 3 and then each curve shooting up so steeply at the 4th hour of observation that by the 5th hour (2nd hour after the change of pH) the percentage of excysted metacercariæ in the changed medium had surpassed that of its control for the same hour after the start of the observation period. Statistical analysis shows that the difference between the total percentage of excysted metacercariæ in the two runs with the pH change and that of the two runs in which pH was not changed was 2.9 times the standard error of the difference. A similar effect was noticed between one run at a straight pH of 7 and a simultaneous one in which the medium was changed from pH 3 to pH 7, the difference between the total percentage of excysted metacercariæ being 2.2 times the standard error of the difference.

At temperature 31° to 32°C, change of pH of the medium, either to pH 7 or pH 9, did not produce the significant increase in percentage of excysted metacercariæ which was noticed at temperature 40°C. No excystation occurred in the runs with change of pH at temperature 22° to 23°C.

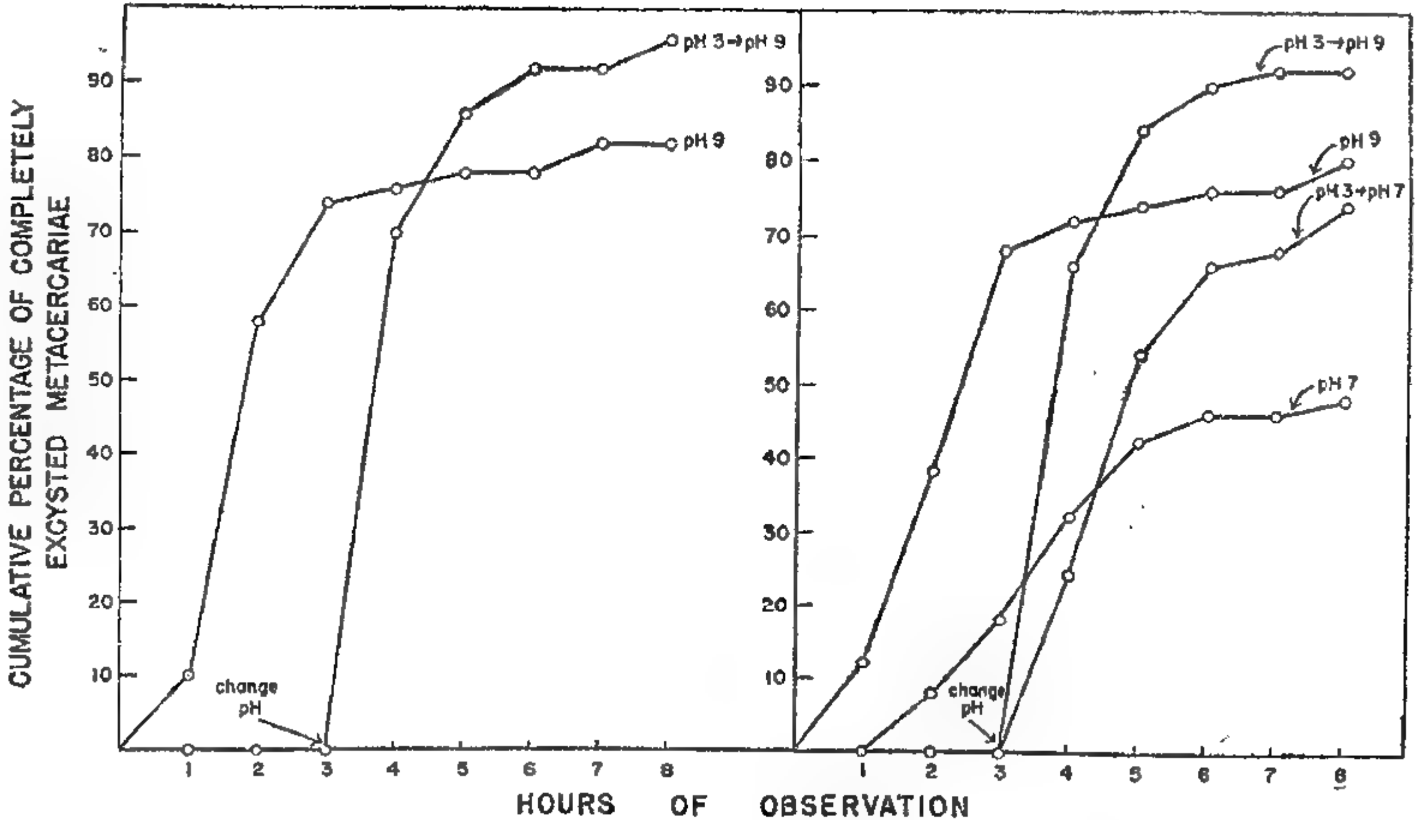


FIG. 8. The effect of change of pH on excystation of *Paragonimus* metacercariæ at 40°C.

DISCUSSION

In his paper on the life history and distribution of *Paragonimus* in North America, Ameel[4] limited his description of the process of excystation of the metacercariæ to the statement that "the larvæ escaped from the cyst through a slit." He included among his figures, however, a drawing of an excysting form at about the same phase of the process as seen in one of our microphotographs (Plate 1, *d*). We have described excystation as we have observed it not only to supplement the information given by Ameel but also because we believe that this process gives an insight into the capabilities and potential of the excysted metacercaria which, after all, is the stage that must migrate through solid body tissues in order to reach the lungs of the host.

In our material, the encysted larva is contained inside a usually spherical cyst with a diameter of about 315 μ measured from the outer surface. Allowing for the thickness of the cyst wall, which is about 16 μ, the available space for the metacercaria inside the cyst is a sphere with a diameter of about 280 μ and therefore a volume of 0.01187 cu. mm. Inside this space is enclosed a larva which in its relaxed and free state has an ovoidal shape with the greatest width at about the junction of the middle and posterior thirds of the body and measuring about 560 μ in length and 225 μ in greatest width.[5] A microscopic study of the metacercaria inside its cyst shows that it is not folded upon itself in order to be contained in the cyst cavity but that it is telescoped into itself antero-posteriorly. To fit into the available space, therefore, the antero-posterior diameter must be reduced to about one-half its length in the relaxed state and the body is formed into a ball from the necessary expansion in width but especially in thickness.

When the encysted organism attempts to assume the normal configuration it has in its relaxed and free state, the pressure it exerts against the confining wall must thus be along its antero-posterior axis. The pressure of the anterior end of the body must be much stronger and more effective than that of the posterior, not only because the anterior portion of the body is more active but also because this portion tapers to a smaller

[4] Ameel, D. G. Amer. Jour. Hyg. 19 (1934) 279-317.
[5] Yogore, et al. Philip. Jour. Sci. 86 (1957) 47-69.

end and its force is therefore concentrated against a smaller area of the resisting cyst wall. When rupture in the cyst wall does occur, it perforce must take place at the site of anterior end pressure. In our observations of many hundreds of excysting metacercariæ, we have never seen the larva emerge from the cyst other than with the anterior end first.

Once the larva has made the breach in the wall, it still has to squeeze itself out of the small exit. We have observed the rent in the cyst wall to be frequently circular though sometimes irregular in shape. When circular, the diameter of the rent may be only in the order of 70 μ and therefore the exit will have an area of only about 0.0038 sq. mm. To pass out through such an exit, the larval body must be converted in segments into a solid cylinder with a cross-section area corresponding to that of the opening. Assuming with good reason that the body volume of the larva is about 0.01187 cu mm, we may picture the entire larval body as being converted into a solid cylinder which must be at least about 3.13 mm long (or about 10 times the diameter of the encysted metacercaria or 5 to 6 times the length of the excysted stage) in order for the larva to pass through the exit.

The above considerations bring out how elastic and plastic the body of the larva must be for successful excystation. Such extreme elasticity and plasticity also allows us to picture with less difficulty how this larva can pass through solid body tissues like muscles although here the larva may be aided by enzymatic activity. Furthermore, the migrating excysted form will have the advantage of being able to grip the substratum with its suckers and thus be able to exert a stronger and better directed force along the path of migration.

Our observations on the excystation of the "M–Fresh," "M–24 Hrs." and "M–8 Wks." metacercariæ showed that not only did a significantly greater proportion of the stored metacercariæ undergo complete excystation within the 2-hour period of observation but also that the stored metacercariæ required a shorter time for accomplishing excystation. These results may be explained on the basis of a stimulation of the stored larvæ to greater activity due to the greater and more rapid change in temperature (from refrigerator temperature to 40°C) to which these larvæ were subjected in comparison with the "M–Fresh" metacercariæ which were subjected to temperature change of only about 32°C to 40°C. A strong argument against

such an explanation, however, is the fact that the "E–Time" of excystation of the stored larvæ was significantly longer than that of the "M–Fresh" metacercariæ, hence the larvæ from the stored metacercariæ could not have been more active but in reality less active than the larvæ from the freshly obtained metacercariæ. The much shorter "I–Time" in the excystation of the stored metacercariæ can be attributed, therefore, not to a more powerful or active larva, but to the weaker obstacle to excystation that the larva met.

Storage of the metacercariæ at 5° to 6°C must have changed the cyst wall as to lessen its physical strength and be more easily ruptured. The relatively weaker larva inside such a cyst may therefore be able to breach its very greatly weakened wall more readily and in a shorter period than could a more active "normal" larva of a fresh metacercaria breach its own wall offering a "normal" resistance.

We do not know the nature of this change in the cyst wall but it apparently takes place with no or so slight an effect on the microscopic appearance of the cyst wall as to have escaped our attention. Since the "E–Time" of the "M–8 Wks." metacercariæ did not significantly differ from that of the "E–Time" of the "M 24 Hrs." metacercariæ, we may reasonably assume that the 8-week period of storage did not significantly alter the vitality of the larvæ which had been stored for that length of time as to make them less active than the larvæ which had been stored only for 24 hours. Such an assumption, coupled with the fact that the "I–Time" for the "M–24 Hrs." and "M–8 Wks." metacercariæ are comparable, leads to the conclusion that whatever change had taken place in the cyst wall as to weaken it had proceeded to a comparable extent in the cyst wall in 24 hours as in 8 weeks and that no further weakening had occurred in the cyst wall of the metacercariæ during the additional long period of storage.

Our observations on the effect of temperature and pH conditions on the excystation of *Paragonimus* metacercariæ show that both conditions must exist at their most favorable levels for optimum excystation. Of the three temperature conditions investigated, temperatures at 40°C and 31° to 32°C were found to be both within the "biologically useful" range for excystation while a temperature of 22° to 23° C was out of this range; a temperature of 40°C was most favorable. Of the four pH levels studied, the most alkaline excystation medium was found to be

optimum with the proportion of excysting metacercariæ decreasing as the excystation medium becomes more acidic until at pH 3 excystation was almost completely inhibited even at an optimum temperature.

At 40°C, definite effects were produced by first placing the encysted metacercariæ in an acidic medium (pH 3) for 3 hours and then replacing the excystation medium with one at pH 7 or pH 9. Not only was there a significant increase in the proportion of metacercariæ which underwent excystation but also a speeding up of the rate of excystation. Whether these effects were due to a stimulation of the larvæ or were mediated by a weakening of the cyst walls as apparently had happened with metacercariæ stored at refrigerator temperature remains to be studied.

While all our observations on excystation were made *in vitro*, some of its implications on the infection of the definitive host in nature may be considered. Successful excystation of the ingested metacercariæ in the digestive system before they can be passed out of the body must be one of a number of factors upon which depend the successful invasion and establishment of *Paragonimus* in the definitive host.

Since excystation requires a certain "biologically useful" range of temperature, it follows that animals with body temperatures lower than the lowest limit of this range will not serve as naturally infected definitive hosts. In warm-blooded animals, the "biologically useful" temperature condition is fulfilled and excystation will take place if other factors are favorable. Excystation will probably not take place in the stomach of animals such as the cat, dog and man because of the acidic medium in this organ but in the small intestines where the favorable alkaline medium is found. Our observations indicate that the passage through the acidic to the alkaline medium serves to accelerate excystation as well as to cause a greater proportion of ingested metacercariæ to excyst.

Insofar as the time element is concerned, our studies indicate that unless the animal is able to discharge the metacercariæ very soon after ingestion, enough time will be available for the completion of excystation. Within one hour, even without pH change, some metacercariæ will undergo excystation at favorable temperature and pH conditions although many more will do so if allowed an additional hour or two. While we have not tried to determine in our experiments the minimum time interval in

the acid medium which will still cause more rapid and successful excystation in the alkaline medium, it would seem that this requirement could easily be attained *in vivo* (at least in some animals) and that the time requirement for excystation would be considerably shortened.

It is certain that excystation *in vivo* will be influenced by many other factors not considered in our simple *in vitro* studies; that factors such as inhibitory and other substances in the host's digestive tract will have to be considered. This is indicated by Ameel's[6] unexplained failure to consistently obtain excysted metacercariæ by the successive use of artificial gastric and pancreatic juice at 37°C. Such considerations caution against direct extrapolation of *in vitro* studies to *in vivo* conditions and emphasize that even simple-looking biological phenomena must be dependent upon the interplay of a host of complex factors.

SUMMARY AND CONCLUSIONS

1. Using *Paragonimus* metacercariæ from naturally infected crabs in the Philippines, studies on the excystation of these metacercariæ *in vitro* were carried out.

2. Microscopic observation of the process of excystation showed that the encysted larva undergoes marked muscular activity within the cyst and causes a rupture at some point of the cyst wall, the larva then "milking" its way to freedom through the small opening by a series of contraction rings passing antero-posteriorly through its body. Great elasticity and plasticity of the organism is required for excystation. A photomicrographic sequence of the process is included in this paper.

3. Time measurements of the process of excystation were made. Freshly obtained metacercariæ at favorable temperature and pH conditions in isotonic salt solution were found to require an average of 70 minutes to complete excystation, with almost 60 minutes being used up for the induction of excystation (from the start of the experiment to the moment of rupture in the cyst wall) and only about 12 minutes for the actual escape of the organism through the exit made. Comparison of this time sequence with that of metacercariæ which had been stored in physiologic salt solution at 5° to 6°C for 24 hours and for 8 weeks showed a definite shortening of the total excystation

[6] Loc. cit.

period with more of the stored metacercariæ completing the process in the same period of time. Our observations give evidence of some loss of muscular ability of the larvæ as a result of storage with the shorter excystation time being apparently due to a disproportionate and marked weakening of the cyst wall.

4. Of three temperature conditions studied, 40°C was found to be optimum for excystation while 22° to 23°C was found to lie outside the "biologically useful" range. Excystation also occurred at 31° to 32°C but this temperature was not as favorable for excystation as 40°C.

5. Of four pH levels studied, pH 9 was found to be optimum for excystation with the proportion of excysting metacercariæ decreasing as the excystation medium becomes more acidic until at pH 3 excystation is almost completely inhibited.

6. Optimum excystation requires the most favorable temperature and the most favorable pH. Optimum excystation was obtained at 40°C and pH 9; excystation was negligible at 40°C and pH 3 and also at pH 9 and 22° to 23°C.

7. At 40°C, a definite increase in the proportion of excysted metacercariæ as well as an acceleration of excystation are obtained by first holding the metacercariæ in an acid medium (pH 3) for 3 hours.

8. The implications of these observations on the infection of the definitive host with *Paragonimus* are briefly considered.

ILLUSTRATIONS

Plate 1

Fig. *a–g*. Photomicrographs of different metacercariæ at various phases of excystation, arranged to show the sequence of the process.

TEXT FIGURES

Fig. 1. "I–Time" plotted against "E–Time" for the excysted metacercariæ in Tables 1, 2, and 3.

2. Excystation of *Paragonimus* metacercariæ at different conditions of temperature and pH.

3. The effect of change of pH on excystation of *Paragonimus* metacercariæ.

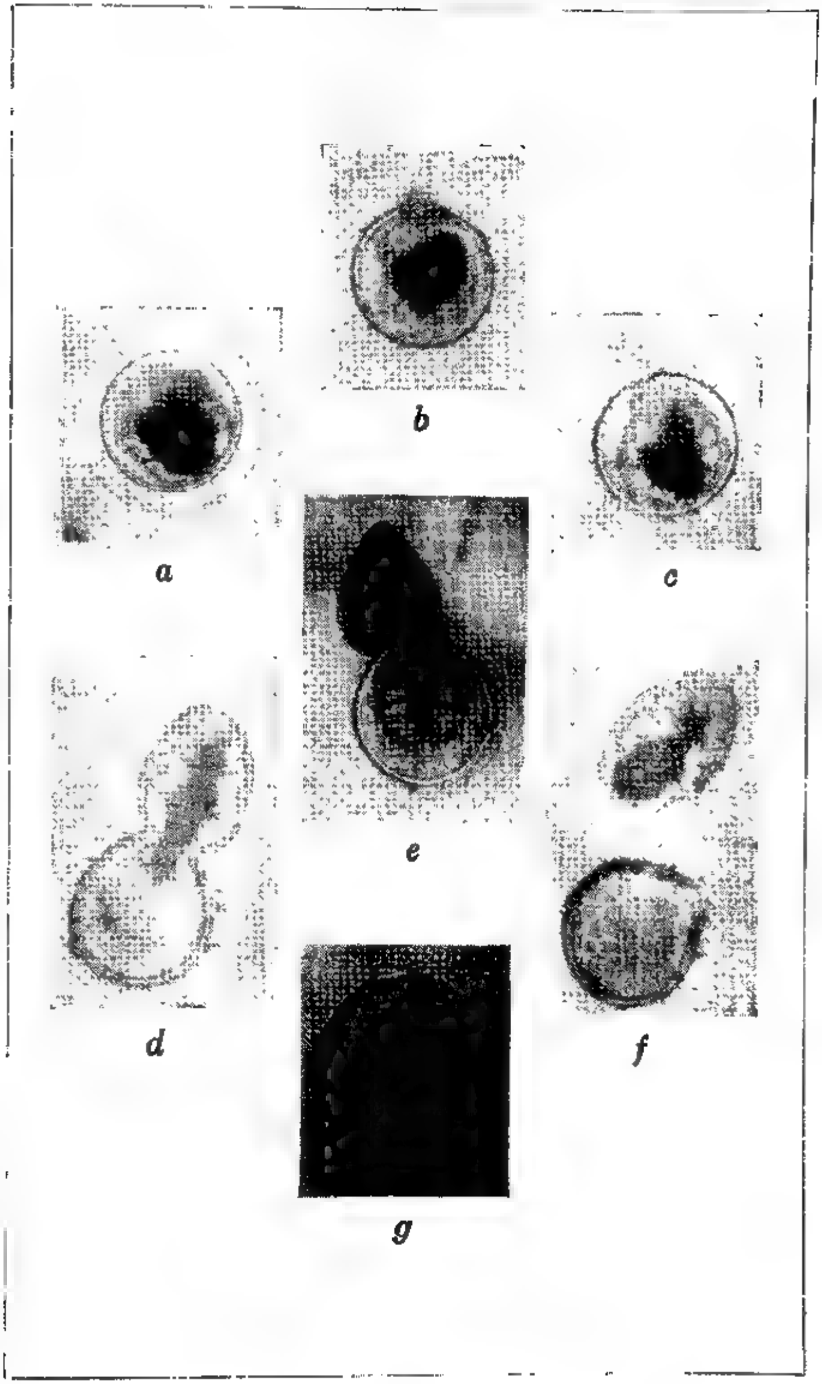


PLATE 1.

THE EXCITED STATES OF GADOLINIUM–155 *

By Jose O. Juliano
Philippine Atomic Energy Commission, Manila

ONE TEXT FIGURE

Gadolinium–155 belongs to the part of the table of isotopes where the shell model barely holds and also where the rotational model of Bohr and Mottelson starts to take into effect due to the non-sphericity of the nucleus. It is therefore quite interesting to be able to know all the details of the modes of decay of these nuclides so that we can interpret and see how the transition from one model to the other takes place and hence correlate these experimental results with the now known theoretical approaches.[1, 2]

The excited states of Gadolinium–155 were studied from the beta-decay of the nuclide Europium–155 which was present in the same source used in the study of the decay of Eu^{154} by Juliano and Stephens.[3]

The first beta-group energy determinations on Eu^{155} was made by Wilson and Lewis[4] and was later followed by the work of Dubey, et al.[5] Both of them reported only two beta groups of energies 150 and 250 kev and intensities 23 per cent and 77 per cent respectively. While this work was in progress, Church[6]

* A preliminary report of this investigation was made under UCRL-3733 (unpublished) of the University of California where the experimental work was done with the support of the United States Atomic Energy Commission. The author takes this opportunity to express his gratitude to the Nuclear Spectroscopy Group for the hospitality and help afforded him during his stay at this Laboratory.

[1] Elliott, J. P. The Nuclear Shell-Model. Handb. Phys. 34 (1957) 241.

[2] Moszkowski, S. A. Models of Nuclear Structure. Handb. Phys. *Ibid.* 411.

[3] Juliano, J. O., and F. S. Stephens, Jr. Phys. Rev. 108 (1957) 341.

[4] Wilson, H. W., and G. M. Lewis. Proc. Phys. Soc. (London) A65 (1952) 656.

[5] Dubey, Mandeville, and Rothman. Phys. Rev. 103 (1956) 1430.

[6] Preprint quoted in Mottelson, B. R., and S. G. Nilsson's article to be published in Kgl. Danske Widenskab Selskab Mat. Fys. Med. (1957). Private communication.

reported a careful study of the beta components of this nuclide and the following are reproduced from him:

Beta component energy Kev	Intensity Per cent	Log ft
250	20	8.1
190	$\leqslant$ 10	$\geqslant$ 8.1
160	40	7.1
150	30	7.2

It is generally agreed that the 250-kev beta particle decays directly to the ground state based on the known energy difference of the two beta groups and also from energy closed-cycle calculations. The gamma transitions of the resulting excited Gadolinium–155 are more confusing and unsettled than that of the beta disintegrations. Rutledge, et al.[7] reported electromagnetic transitions of 60, 87, 106, and 132 kev. However, Lee and Katz[8] observed in addition 18.7 and 136.8 kev from their conversion electron line studies while Church and Goldhaber[9] reported a negative result for the 132-kev transition. The real problem boils down to what is the first excited state of Gd^{155}. Wilson and Lewis suggested 85 kev from their studies while Dubey and his group supported the 19-kev level. From their experimental results it is impossible to correctly assign either the 19- or 85-kev levels although if Church's beta-particle distribution would be assumed reliable the 85-kev level would be preferred. However, beta end-points alone are not definitive specially after resolving more than two groups in the beta-particle distributions and in this case where some energy groups are separated only by a meager 20 kev. From coincidence measurements and energy summations the 85 and 19 kev are in coincidence and originate from the 106-kev level. It has been observed, both by Wilson and Lewis and by Dubey, et al., that the 19-kev transition is a highly converted transition. From Coulomb excitation, 60- and 145-kev levels in Gd^{155} belonging to the rotational band $K=3/2$ and odd parity, have been reported.

EXPERIMENTAL

Preparation of the Eu^{155} source.—The Eu^{155} in this study was prepared by irradiating plutonium in the form of napkin rings for about two years in the Materials Testing Reactor at Arco, Idaho. In this manner, fission produced Eu^{155} was made with

[7] Rutledge, Cork, and Burson. Phys. Rev. 86 (1952) 775.

[8] Lee, M. R., and R. Katz. Phys. Rev. 93 (1954) 155.

[9] Church, E. L., and M. Goldhaber. Phys. Rev. 95 (1954) 626A.

Eu^{154} as the only contaminant among the europium fraction. In order to separate the europium from the plutonium and the other fission products, a chemical separation similar to that of Juliano and Stephens' was performed. A mass spectrographic analysis showed no other contaminants.

Conversion-electron measurements.—The conversion-electron lines of Eu^{155} were studied with four 180° permanent-magnet electron spectrographs described previously by Smith and Hollander.[10] These instruments had different magnetic-field intensities to cover the energy range from almost a few kev to about 3 Mev. The conversion-electron lines were recorded photographically on glass-backed Eastman Kodak No-Screen x-ray plates having an emulsion thickness of 25 microns. The resolution (full width of a peak at one-half its maximum) of these spectrographs in the present experiment was about 0.1 per cent. In order to obtain the best possible energies the 123.07-kev

TABLE 1.—*Conversion electrons of Eu^{155}, their visual relative intensities and multipolarity assignments.*

Gamma-ray transition energy	Conversion-electron energy	Shell assignment	Conversion electron visual relative intensity*		Assigned multipolarity
			I**	II***	
kev	*kev*				
18.8	10.40	L_I	vvw	----	M1 (E2)
	10.86	L_{II}	vvw	----	
	10.63	L_{III}	vvw	----	
41.6	33.16	L_I	vw	----	E1 or M1 (E2)
	33.68	L_{II}	vw	----	
	34.35	L_{III}	vw	----	
59.9	9.67	K	vvw	----	M1 (E2)
	51.53	L_I	vvs	wm	
	51.9[illegible]	L_{II}	m	vvw	
	52.56	L_{III}	vvw	--	
85.9(?)	35.68	K	vw	----	E1 (?)
86.5	36.27	K	vvs	m	E1
	78.16	L_I	ms	m	
	78.54	L_{II}	w	vw	
	79.27	L_{III}	wm	wm	
	84.57	M_I	wm	vvw	
	86.01	N_I	vw	vvw	
105.2	54.97	K	vvs	s	E1
	96.70	L_I	ms	m	
		L_{II}	----	----	
	97.90	L_{III}	w	vvw	

* The symbols mean: *m*, moderate; *s*, strong; *ms*, moderately strong; *vvs*, very very strong; *w*, weak; *wm*, weakly moderate; *vw*, very weak; *vvw*, very very weak.

** Film exposed for three days.

*** Film exposed for one day.

[10] Smith, W. G., and J. M. Hollander. Phys. Rev. **101** (1956) 746.

transition of Eu^{154}, which was measured by a bent-crystal spectrometer by Boehm and Hatch[11] and present with the Eu^{155}, was used as an internal standard.

The energies and visual intensities of the conversion electron lines assigned to Gd^{156} as obtained from the permanent-field spectrographs are given in Table 1.

Assignment of the conversion electron and their multipolarities.—From the energies of the conversion-electron lines which are known to an accuracy of 0.1 per cent the gamma-transition energies were calculated. The transitions assigned to Gd^{165} are: 18.8, 41.6, 59.9, 85.9, 86.5, and 105.2 kev. Each one will be discussed in the succeeding sections and their most appropriate multipolarities based on their relative conversion-line intensities and the theoretical conversion-electron coefficients calculated by Rose, et al.[12] and Sliv and Band [13] will be discussed.

18.8-kev transition.—During the first short exposures, this transition was not observed due to its low intensity and because of the poor electron-detecting efficiency of the emulsion in this energy range. However, other plates were exposed as long as possible without the beta spectrum producing a blackening on the plate that makes reading the conversion lines impossible. All the three lines were seen, and it is with great certainty that this 18.8-kev transition exists in Gd^{156}. Although not a very reliable multipolarity can be assigned to this transition, it seems that an E1 or an M1 (E2) mixture agrees with the observed intensities of the L lines. Using Rose's theoretical L-conversion coefficients, the L-subshell conversion-electron relative intensities are compared with the observed intensities:

Multipolarity	Relative Intensity $L_{I}:L_{II}:L_{III}$
E1	1.2:1.0:1.7
E2	0.005:1.0:1.4
M1	11.0:1.0:0.2
M2	19.5:1.0:10.5
Observed	vvw:vvw:vvw

[11] Boehm, F., and E. N. Hatch. Nuclear Data Card No. 57-1-95 (1957).

[12] Rose, M. E., G. H. Goertzel, and C. Swift. L-shell internal conversion coefficients. Privately distributed.

Rose, M. E., G. H. Goertzel, and C. L. Perry. ORNL-1923 (1955). Unpublished.

Rose, M. E. L-shell internal conversion coefficients with finite nuclear size included. Privately distributed.

[13] Sliv, L., and J. Band. Tables of Gamma-Ray Internal Conversion Coefficients, Part I. (Isdatelstvo Akademia Nauk SSSR 1956.)

The L-subshell conversion electrons have similar intensities which suggest an E1 multipolarity. However, an M1 (E2) mixture may also produce the same relative intensities. Since the 105.2- and 86.5-kev electromagnetic transitions are definitely known to be almost pure E1, an M1 (E2) mixture multipolarity for the 18.8-kev transition is preferred. This assignment agrees with the experimental findings of Wilson and Lewis and also of Dubey, et al. in which they concluded that the 18.8-kev transition is a very highly converted transition. In their works, they failed to see this electromagnetic transition with proportional counters but observed only the conversion electrons.

41.6-kev transition.—The L_I,L_{II},L_{III} conversion electrons were observed for this transition and again with similar intensities, although the lines are more intense than the 18.8 kev. From Rose's theoretical L-conversion coefficients, the L-subshell intensity ratios are:

Multipolarity	Relative intensity L_I:L_{II}:L_{III}
E1	2.4:1.0:1.4
E2	0.02:1.0:1.3
M1	12.0:1.0:0.2
M2	12.0:1.0:4.5
Observed	vw:vw:vw

The data show that this can either be an M1 (E2) mixture or a pure E1 transition. From energy difference considerations this transition does not fit very well the transition between the 145.8-kev and 105.2-kev levels. However, it must be remembered that the 145.8-kev level energy was based only on the energy of the K-line attributed to that of the 85.91-kev electromagnetic transition. From this experiment, no clear and conclusive proof for the presence of the 146-kev level was obtained as compared to what was observed by Bjerregaard and U. Meyer-Berkhout [14] and also by Heydenburg and Temmer [15] in their Coulomb excitation experiments. However, it will be shown later that theoretically, the beta group feeding the supposedly present 146-kev level from Eu^{155} may be quite small and the detection of the transitions from this state would be difficult.

If we consider the possibility of 18.8 kev being the first excited state, this 41.6-kev gamma ray would fit quite well the transition from the 59.9-kev level to the 18.8-kev level. Hence,

[14] Bjerregaard, J. H., and U. Meyer-Berkhout. Z. Naturforsch. 11a (1956) 273.

[15] Heydenburg, N. P., and G. M. Temmer. Phys. Rev. 104 (1956) 981.

there would be two gamma rays of almost similar energies, about 18.8-kev, one to account for the de-excitation of the 18.8-kev level, and the other to feed the 86.5-kev level from the 105.2-kev state. The fact that there are two gamma rays of the same energy may explain the rather high intensity of the L-subshell conversion electrons of the 18.8-kev transition.

Another approach to explain the impossibility of the 41.6 kev being the transition between the 145.8- and the 105.2-kev levels would be the following. If 41.6 kev is the transition between the 145.8- and the 105.2-kev levels of Gd^{155}, it should be an E1; and if the 14.6 kev is an E1 and the 85.91 kev is an M1 their conversion electron coefficient are 0.01 for the L_I and 3.5 for the K of 41.6 and 85.01 kev respectively. Therefore the gamma intensity of the 41.6 kev should be about 300 times as intense as that of the 85.9 kev for this multipolarity assignment to be correct. Such is not the case experimentally, for they seem to have the same intensity [6] and from Coulomb excitation experiments,[16, 17] only the 86-kev gamma ray was seen coming from the 146-kev level. However, the 41.6-kev transition is in the K x-ray region of gadolinium, which is 41.8 kev, and that would make its detection difficult. From the gamma-spectrum curve of Heydenburg and Temmer, the presence of the 41.6 kev cannot be completely discounted because of their intense K x-ray peak.

The presence of this transition strongly supports the presence of an 18.8-kev level and puts some doubt on the validity of the beta end-points of Church.

59.9-kev transition.—Before the results on Coulomb excitation were published, it was perplexing to note the presence of a strong transition of 59.9 kev, which was hard to fit into the then known decay scheme of Eu^{155}, especially when the gamma spectrum did not show the presence of any 60-kev transitions and some investigators did not find this transition. However, its presence was positively due to either Eu^{155} or Eu^{154}, since the sample contained nothing more, as shown by mass analysis. Fortunately, this state was also excited by Coulomb excitation[16, 17] and is the first excited state of the rotational-band spectrum of Gd^{155}. The relative subshell intensities are:

Multipolarity	Relative intensity $L_I{:}L_{II}{:}L_{III}$
E1	3.2:1.0:1.3
E2	0.05:1.0:1.1

[16] Bjerregaard and Meyer-Berkhout, loc. cit.
[17] Heydenburg and Temmer, loc. cit.

Multipolarity	Relative intensity $L_I:L_{II}:L_{III}$
M1	11.1:1.0:0.2
M2	10:1.0:1.0
Observed	wm:vvw:- vvs:m:vvw

The fact that the L_{III} was not seen in the short exposure runs strongly suggests an M1 transition. However, it is reasonable that there is also an E2 mixture in this transition. Church and Goldhaber [18] calculated this amount of mixing to be 94 per cent M1 and 6 per cent E2 from the conversion coefficients of Rose [19] and his conversion electron intensities, which agrees with this investigation. From Coulomb excitation, a 5 per cent E2 mixture was reported. Furthermore, the possibility of the 59.9-kev being an E1 is discounted by the fact that it was excited by Coulomb excitation, which so far, with the exception of the weakly excited 109-kev level in F^{19}, has produced only E2 transitions. [20]

86.5-kev transition.—In terms of conversion-electron intensities, this is the strongest transition observed in Gd^{155}. From the relative subshell intensities below:

Multipolarity	Relative intensity $L_I:L_{II}:L_{III}$
E1	4.1:1.0:1.1
E2	0.2:1.0:0.05
M1	11.3:1.0:0.2
M2	9.0:1.0:2.0
Observed	m:vw:wm ms:w:wm

the only possible transition multipolarity is E1 or M2. Rutledge, et al.[21] assigned this an an E2 transition based on their K/L ratio of 8.0 ± 2.8. Lee and Katz [22] found the K/L ratio to be four. From Sliv's K-conversion coefficient and Rose's L-conversion coeficients corrected for screening, the conversion

[18] Loc. cit.
[19] Loc. cit.
[20] Alder, et al. Revs. Modern Physics 28 (1956) 432.
[21] Loc. cit.
[22] Phys. Rev. 93 (1954) 155.

coefficients for the possible multipolarities are presented in Table 2.

The only conclusion from the K/L ratio is that this transition cannot be an M2 transition. The possible assignments are M1, E2, or E1, but as will be proved shortly, this 86.5 kev is an E1 transition.

TABLE 2.—*Conversion coefficients of the 86.4-kev transition of* Eu^{155}.

Multipolarity	Conversion coefficients					Relative intensity K/L
	K	L_I	L_{II}	L_{III}	L Total	
E1	4.0	0.5	0.03	0.005	0.54	7.4
E2	28.0	6.5	0.7	1.4	8.6	3.3
M1	0.4	0.04	0.01	0.01	0.06	6.7
M2	1.3	0.2	1.1	1.1	2.30	0.6

The proof is as follows: If the 105.2 kev is an E1 transition, an independent check of the multipolarity of the 86.5-kev can be calculated using the gamma spectrum of Dubey, et al.[23] The relative intensities of the 42-kev gadolinium K x-rays, and 84-kev and 102-kev photopeaks were measured with a planimeter, corrected for crystal efficiency and iodine escape peak. The results are:

Energy of gamma ray	Relative intensity (arbitrary units)
42 (K x-rays)	14.9
84	16.3
102	9.8

The K-flourescence yield of gadolinium from Gray's[24] curve is 0.93, and hence the electron intensity of all the transitions above 50 kev, K-binding energy of gadolinium, is 16.0. The K-conversion coefficient for an E1 transition of 102 kev energy is 0.24, and hence the K-conversion-electron intensity is 3.8. Assuming that the conversion-electron contributions of the other transitions are small compared with the 84-kev and 102-kev transitions, an upper limit for the K-conversion-electron coefficient of the 87-kev transition can be calculated, and this turns out to be 0.75. From Sliv's K-conversion coefficients for an 86-kev transition, the theoretical values are:

Multipolarity	K-conversion coefficient
E1	0.22
E2	0.92
M1	1.6
M2	13.0
Observed	0.75

[23] Loc. cit.

[24] Gray, P. R. Phys. Rev. 101 (1956) 1306.

The results show that the 84 kev is either an E1, M1 or an E2, but cannot be an M2. However, the relative L-subshell conversion-electron intensities limit the possible multipolarities only to an E1 or M2. Hence, by combining the interpretations obtained from the gamma intensities and the L-subshell intensities it can be concluded that the 86.5 kev is an E1 transition.

Another way of looking at this is to assume that all the electron intensity of 16.0 is due to the K-conversion electrons of the 86.5-kev transition. In this way, the maximum K-conversion coefficient of the 86.5-kev transition amounts to 0.98. Hence, it eliminates without any doubt the possibility that the 86 kev is a magnetic transition: more so if it is an M2 transition. Similarly, we can calculate the maximum theoretical K-conversion coefficient for the 105.2-kev transition, assuming that all the electron intensity 16.0 is due to its K-conversion electrons. From this assumption, $\alpha_K \leqslant 1.6$ for the 105.2-kev transition.

The K-conversion coefficients as given by Sliv for the 105-kev transition are:

Multipolarity	K-conversion coefficient
E1	0.2
E2	1.0
M1	1.7
M2	10.0
Observed	$\leqslant$ 1.6

Hence, the probability that the 105.2 kev is an M2 transition is very slim, a reasoning which would be used shortly.

By comparing the intensities of the K-conversion lines of the 105.2- and 86.5-kev transitions, which are supposed to be both E1, a glaring inconsistency was noted in the permanent-magnet spectrograph plates. Since the 87-kev is more intense gamma-wise, it should be expected that the K lines of the 87 kev should be stronger than the K line of the 105.2 kev; but this was not so. This can only be true if the 105.2-kev K line is composed of conversion lines from two or more different transitions or if the multipolarity assignments are incorrect. Fortunately, these two K peaks were strong enough to be seen in the beta spectrum obtained from the magnetic spectrometer, and their relative intensities can be compared after subtracting the beta background. The results are:

Transition	K-conversion-electron intensity (arbitrary units)
86.4 kev	7.4
105.0	6.4

which is in agreement with the assignment of both the 86.5 and 105.2 kev as E1 transitions. Incidentally, this may show the limits of accuracy in reading relative intensities by visual comparison.

105.2-kev transition.—This is in coincidence with the 150-kev beta component, and is the origin of the 18.8- and 86.5-kev transitions. From the relative intensities of the L-subshell conversion electrons and Rose's[25] conversion-coefficient data, the multipolarity possible for the 105.2 is either an E1 or an M2, as seen below:

Multipolarity	Relative intensity $L_I:L_{II}:L_{III}$
E1	4.7:1.0:1.2
E2	2.1:1.0:1.0
M1	1.3:1.0:1.9
M2	9.0:1.0:1.9
Observed	ms:—:w m:—:vvw

However, based on the conclusions derived from the gamma-ray intensities of Dubey, et al., the possibility of an M2 transition for the 105.2 kev is entirely discounted, leaving only the E1 as the logical assignment for this transition, and is in agreement with all the experimental data.

145-kev transition.—Heydenburg and Temmer observed this transition in their Coulomb excitation of Gd^{155}. However, in the conversion-electron studies, no positive evidence of the 145-kev transition was observed. This would lead one to believe that it is not being populated very heavily from the beta decay of Eu^{155}, which is what the beta-component results show. (Table 3)

TABLE 3.—*Classification of the Eu^{155} beta components.*

Final state (kev)	ΔI, Δπ, Type	ΔK, ΔN, Δn_z, ΔΛ	Asymptotic classification	Experimental log ft data	
				Church	Rutledge, et al.
145.8	1, yes, 1st forbidden	1,1,1,2	Hindered	----	-
105.2	0, no, allowed	0,2,3,2	do	7.2	6.8
86.5	1, no, allowed	1,2,4,2	do	7.1	----
59.9	0, yes, 1st forbidden	1,1,1,2	do	≤8.1	----
18.8	1, yes, 1st forbidden	1,1,2,1	do	----	----
0.0	1, yes, 1st forbidden	1,1,1,2	do	8.1	8.1

[25] Loc. cit.

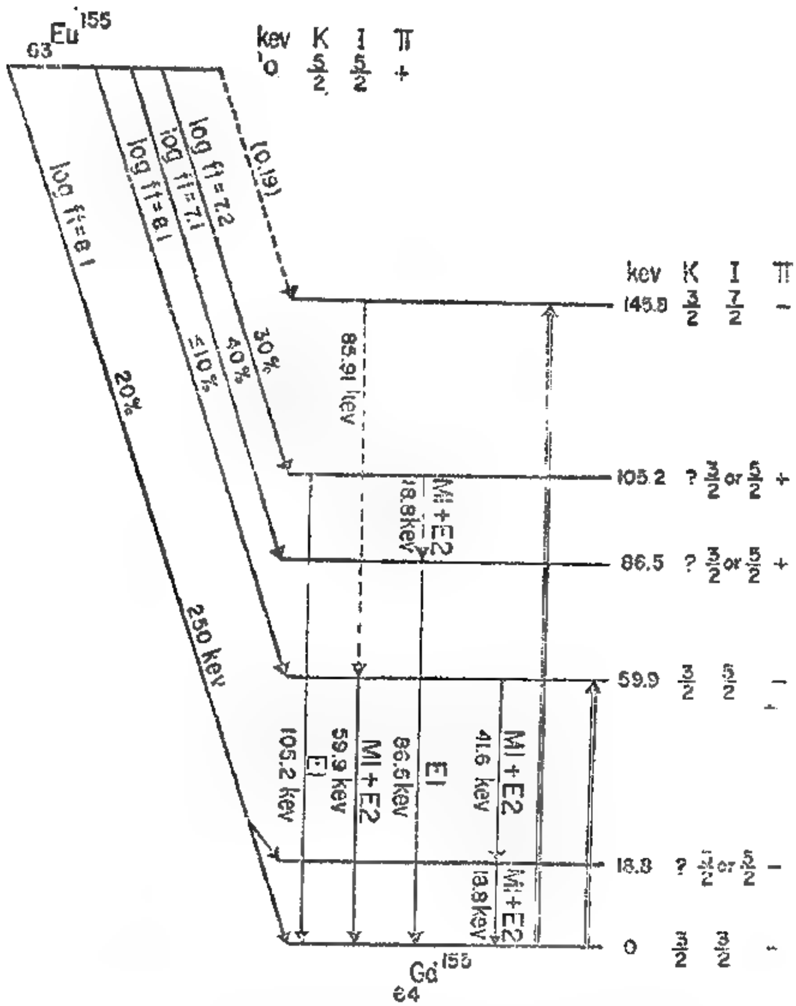


FIG. 1. Decay Scheme of Eu^{155} showing the excited states of Gd^{155}.

Decay scheme.—The proposed decay scheme for Eu^{155} is given in Fig. 1. The ground state of Gd^{155} is assigned a spin of 3/2 from the work of Jenkins and Speck,[26] and a negative parity from the magnetic-moment results of Speck.[27] It is the first level of the rotational band K = 3/2− as deduced from the

[26] Jenkins, F. A., and D. R. Speck. Phys. Rev. 100 (1955) 973A.
[27] Speck, D. R. Phys. Rev. 100 (1956) 1725.

Coulomb excitation experiments. Using Nilsson's[28] diagram for highly deformed nuclides, the most logical assignment for this level is $\Omega = 3/2 = I$, $K = 3/2$, $\pi = -$, $N = 5$, $n_Z = 2$, and $\Lambda = 1$, or in short as $[3/2-, (5, 2, 1)]$.

Since the 59.9-kev transition is mostly an M1 transition, the first excited level of the rotational band should have a spin of 1/2, 3/2, or 5/2 and odd parity. However, it is known that this is the first excited state of the rotational band and therefore is the $I = 5/2$, $K = 3/2$, $\pi = -$, $N = 5$, $n_Z = 2$, and $\Lambda = 1$, which agrees with the experimental results. Also, the beta intensity of $\leqslant 10$ per cent is in agreement with the theoretical prediction of Alaga, et al.[29] for beta transitions to members of a rotational band (Table 4). If this is the 5/2, 3/2− state we can calculate the second excited state of the rotational band using Bohr and Mottelson's[2] formula, and the predicted 7/2, 3/2− state is 145.2 kev. The presence of such a state has been confirmed by Coulomb excitation and the transition between the 145.8- and the 59.9-kev levels has been only tentatively seen in this investigation. On the other hand, the 145.8-kev transition was only observed in Coulomb excitation. It was not surprising however, to note the absence of the 145.8-kev transition in the conversion-line spectrum since its reduced transition probability is 3.8 times as small as the 85.9-kev and also 7.5 times less converted. So, the rotational band structure of Gd^{155} seems well established. The 105.2-kev and 86.5-kev levels are fed directly by the two allowed hindered beta-decay types, and hence the reason for their higher intensities. (Table 4)

TABLE 4.—*Calculated and experimental abundances of the beta components of Eu^{155} to the members of the rotational band of Gd^{155}.*

Beta end point	Final state	Without energy-dependence correction		Corrected for energy dependence		Experimental relative intensity
		C^2	Relative intensity	C^2/t	Relative intensity	
			Per cent		*Per cent*	*Per cent*
250 kev	3/2, 3/2−	0.667	(20.0)	(0.667)	(20.0)	20
190	5/2, 3/2−	0.285	9.0	0.190	6.0	≤10
104	7/2, 3/2−	0.048	1.4	0.007	0.2	----------

Since the 105.2-kev is an E1, the 105.2-kev level should be of even parity and the spins could be 1/2, 3/2, or 5/2. The 59.9-kev

[28] Nilsson, S. G. Klg. Danske Videnskab. Selskab. Mat. Fys. Medd. (16) 29 (1955).

[29] Alaga, Alder, Bohr, and Mottelson. Kgl. Danske Videnskab. Selskab. Mat. Fys. Medd. (9) 29 (1955).

state should be of odd parity, and its spin may either be ½, ³⁄₂, or ⁵⁄₂ due to the 59.9-kev transition's M1 (E2) character. Since this is a member of the well-known rotational band K = ³⁄₂− a ⁵⁄₂− assignment was chosen. Hence, the 18.8-kev level should be of odd parity and spin of either ³⁄₂ or ⁵⁄₂. The 86.5-kev level has even parity, the 86.5-kev gamma ray being an E1, and spin ³⁄₂ or ⁵⁄₂. The 145.8-kev level was given a ⁷⁄₂− assignment.

The final assignments of levels is shown in Fig. 1, and a test of their correctness will be shown in the discussion of the beta components.

The log ft of the beta components are rather high if based on the Gamow-Teller selection rules. However, these unusually high log ft values are explained when we use Alaga's modified selection rules. The ground state of Eu^{155} was assigned the Nilsson state ⁵⁄₂, +, 4, 1, 3, based on its known spin. The analysis as shown in Table 3 classifies all the transitions as based upon the Nilsson states to be hindered, and hence the reason for the slightly higher log ft values.

Using Alaga, et al.'s transition probabilities to members of a rotational band, the squares of the Clebsch–Gordan coefficients, C^2, were calculated for K_i = ⁵⁄₂ to K_f = ³⁄₂, ⁵⁄₂, and ⁷⁄₂ with $\Delta I = 1$. With 20 per cent (assumed) intensity for the ground state, the theoretical beta intensities for the excited states of the rotational band were calculated. Since the square of the Clebsch-Gordan coefficients[80] are not energy-dependent, these were corrected, and the results are given in Table 4.

The agreement between theory and Church's experimental intensities is remarkable, and this may explain why the 104-kev beta group was not seen. It is noteworthy to mention also that the 86.5-kev transition, owing to its very strong intensity, cannot be used as the transition between the second and first excited states of the rotational spectrum, although its energy would be right for such a transition.

[80] Condon, E. U., and G. H. Shortley. Theory of Atomic Spectra (Cambridge University Press, London, 1935).

GADDANG PHONOLOGY

By MADELINE TROYER

Summer Institute of Linguistics, University of North Dakota

The Gaddangs [1] are a semi-nomadic people living in scattered areas of the Cagayan Valley and eastern Bontoc of north-central Luzon. There are about 2,500 speakers of this linguistic group, who still retain their own distinct culture.

The principal informant used in the preparation of this paper was Mr. Lucio Lappao, a barrio lieutenant of Butigui, Bontoc. He is approximately forty-five years old, and in addition to his own dialect speaks Ilocano, Tagalog, and English.

The data used for this paper were gathered during the years 1957 and 1958 under the auspices of the Summer Institute of Linguistics.[2]

The phonology of Gaddang can be described as a hierarchical structure based upon the phonemes. Hence I begin my description by setting out the individual phonemes in four classes—semi-consonants (S), consonants (C), vowels (V), and stress. These phonemes in turn combine to make up the syllable. In describing the syllable, we give the distribution of the individual phonemes. Syllables in turn combine to form the phonological word.[3] In discussing the phonological word, we give definition and description with specific detail as to the resultant combinations of phonemes at syllable boundaries within these phonological words. We further suspect that phonological words combine into phrases and phrases into longer sequences—such as the sentence—with these two phonological units being delimited by intonation contours. However, we have not given sufficient time to the study of such phrases or longer sequences and have not included them in this paper.

PHONEMES

1. Gaddang phonemes are divided into the four classes on the basis of their distribution. The interpretation of non-

[1] This group is often referred to as the pagan Gaddangs in contrast to the Christianized Gaddangs of Nueva Vizcaya. The name is pronounced Gàdang by the people themselves.

[2] For various valuable suggestions I am indebted to my colleagues, Dr. Howard McKaughan and Felicia Sadowski.

[3] The term "word" in this paper always refers to the phonological word as defined in section 3.1.

syllabic vocoids presents a special problem. Non-syllabic vocoids (*y* and *w*) have usually been interpreted in Philippine languages as either vowels [4] or consonants.[5] Since in Gaddang these high, front and back non-syllabic vocoids do not conform to the distribution of either consonants or vowels, we have set up the third group, semi-consonants (S).

SEMI-CONSONANTS

1.1. The following examples are illustrative: *yóta* 'there', *siyoŋ* 'shade', *bálay* 'house', *middyob* 'will blow', *madíyot* 'will bathe', *wánaŋ* 'river', *bóˀlaw* 'throat', *masswéldo* 'will pay wages'. The evidence for the interpretation of these non-syllabic vocoids as semi-consonants follows.

1.11. All sequences of vocoids in Gaddang contain at least one non-syllabic member, and no two syllabic vocoids occur contiguously; there are thus no non-suspect vowel sequences. Morphemes such as the following will therefore not permit the interpretation of these non-syllabic vocoids as vowels /i/ and /o/, since this would yield patterns such as VVV, VVVV, or even VVVVVV: *kayó* 'you pl.', *ˀáwan* 'no, none', *wáwaŋ* 'river', *wawáyi* 'relatives'.

1.12. The distribution of these non-syllabic vocoids is similar to that of the consonants in that they may occur initial, between vowels, final, and in geminate clusters.[6] Examples: *wáwaŋ* 'river', *bóˀlaw* 'throat', *yóta* 'there near', *ˀíyoŋ* 'nose', *bafáy* 'girl', *sáyyaŋ* 'spear', *doggyáwwi* (a boy's name).

1.13. The distribution of these non-syllabic vocoids is different from the consonants in that they may occur following a consonant within the same syllable, e.g. *kwí* 'to', *míd.dyob* 'will blow', *na.pat.twél* 'carried on a pole'.

1.14. There are no reverse sequences of semi-consonant plus consonant (even across syllable boundaries).

1.15. There are no non-suspect CCC sequences. Thus the following morphemes would further suggest that non-syllabic vocoids are not regular consonants: *maggyán* 'will remain', *paka ˀommwán* 'joking', *nappyá* 'good'.

[4] McKaughan, Howard. The Inflection and Syntax of Maranao Verbs. Inst. Nat. Lang., Manila (1958) 3.

[5] Gieser, Richard C. The phonemes of Kalinga. Oceania Linguistic Monographs (Univ. Syd., Austr.) No. 3 (1958) 20–21.

[6] Geminate clusters are made up of re-articulated phonemes when pronounced syllable by syllable, but are long phonemes in fast speech.

1.16. In some Philippine languages words such as *míddyob, maggyán, nəppya* are interpreted as **míddiyob, *maggiyan, *nəppiya* in order to conform to the syllable patterns allowed in those languages.[7] We do not consider this possible in Gaddang (*1*) since the syllable *dyob* is only one phonetic syllable no matter how slowly it is pronounced; and (*2*) because such an interpretation would conflict with similar syllables known to contain high syllabic vocoids. Note the following: *ma.dí.yot* 'will bathe', *ma.ki.yáy.yam* 'will visit' and *míd.dyob* 'will blow'; *pí.yək* 'baby chick', *nəp.pyá* 'good', and *nə.páp.pya* 'good'; *ka.to.wa.ŋán* 'parent-in-law' and *na.pat.twél* 'carried on a pole'.

1.17. One might conclude that such sequences as *dw, mw*, etc., are then complex single consonants. However, *y* and *w* have been found in the following combinations: *py, by, ty, dy, ny, ly, ky, gy, ŋy, bw, mw, tw, dw, nw, lw, sw, kw.* Therefore to conclude that *y* and *w* are in these instances palitalization and labialization of the preceding consonant would more than double the number of consonant phonemes. Examples: *nəppyá* 'good', *agabyág* 'living, *bityótyo* (a boy's name), *míddyob* 'will blow', *pínnyə* 'pineapple', *pallyót* 'short flute', *kyáw* 'bow wow (of a small puppy)' *maggyán* 'will remain', *ŋyáw* 'meow', *ginabwát* 'got up', *paka?ammwán* 'joking', *napattwél* 'carried on a pole', *?adwá* 'two', *mamánnwet* 'fishing with hook', *mallwág* 'boiling', *masswéldo* 'will pay wages', *kwí* 'to'.

CONSONANTS

1.2. The consonants are non-vocoids which occur as bilabials, alveolars, velars, and glottal stop. The bilabials include voiceless and voiced stops (*p, b*), fricative [ƥ] = (*f*), and nasal (*m*). Examples: *mapósit* 'will pluck', *mabósit* 'is pregnant' *pókkal* 'turtle banana', *bókal* 'seed', [*ƥókal*] = *fókal* 'udder' *pátak* 'nail', *bátak* 'pattern, design', *mátak* 'my eye'.

Alveolars include both voiceless and voiced stops (*t, d*), sibilant (*s*), nasal (*n*), trilled vibrant (*r*), and lateral (*l*). Examples: *tálit* 'thunder', *dálit* 'hard, stony ground', *dá?dap* 'large stone', *dá?lap* 'floor' *nána* 'pus', *tálon* 'woods', *táron* 'year', *sápit* 'word'.

Velars include voiceless and voiced stops (*k, g*) and nasal (*ŋ*), e.g. *makátal* 'itchy', *káddan* 'leg muscle', *gáddaŋ* 'skin', *ŋá?ŋət* 'tobacco'.

[7] Gieser, *Ibid.*

Glottal stop (ʔ),[8] e.g. *maʔátal* 'embarrassed, shy' *ʔappát* 'four', *bóʔlaw* 'throat'.

VOWELS

1.3. The vowels are syllabic vocoids which occur as syllable nuclei and are in front, central, and back positions. Front vocoids are high and mid (*i* and *e*). Examples: *díla* 'tongue', *sóbi* (fish species), *ʔítan* 'to see', *bébay* 'sea', *gafénin* 'evening'. These vocoids have the allophones [ɩ] and [ɛ] respectively, which occur only in syllables closed by a consonant, e.g. [*bíɩ̃g*] *bíñg* 'lips' [*dɩndɩŋ*] *díndiŋ* 'wall' *ʔawɛ́g ʔawég* 'brook', *nɛ́kkwa nékkwa* 'placed'.

Central vocoids are mid and low (*ə* and *a*). Examples: *tákad* 'broom', *tákəd* 'floor tying', *ʔílap* 'knife', *ʔíbək* 'mosquito', *kápat* 'cotton', *naləppət* 'blind'.

The back vocoid is mid-high to high (*o*),[9] e.g. *ʔiyoŋ* 'nose' *kósa* 'cat', *mótoŋ* 'face'.

STRESS

1.4. Primary stress is not predictable in terms of any phonological feature.[10] When words are spoken in isolation, primary stress may move from syllable to syllable; the position of primary stress is therefore determined by examining words in a larger context. Examples: *mətákaw* 'will steal', *mattakáw* 'will borrow', *palátaŋ* 'jaw bone', *matarabáfo* 'will work'.

A secondary stress occurs on the first syllable of four or five syllable words, and since always predictable, it is non-phonemic. Examples: [*màbbalafíŋgan*] *mabbalafíŋgan* 'will become numb', [*ʔàlifámbaŋ*] *ʔalifámbaŋ* 'butterfly', [*màkkakaráyyəm*] *makkakaráyyəm* 'will visit (many)', *salawínit salawínit* 'trousers'.

SYLLABLES

2.1. Definition. A syllable is composed of a vowel nucleus always preceded by C and/or S and optionally followed by C or S.

[8] The voiceless glottal fricative (*h*) has been observed in the loan *hwebit* 'Thursday'.

[9] Freely fluctuates with [u] except in a very few instances which seem to contrast, e.g. *dólam* 'inside', *dúlam* 'mist, fog', *matól* 'will call dog', *mattúl* 'will pout'. Since such instances are so infrequent and since it is possible that such contrasts are not being heard correctly, the functional load is so low that it has not seemed valid to include in the paper.

[10] Primary stress occurs more frequently on the penult.

2.2. General structure. There are nine syllable types which result from the various combinations of S, C, and V. Examples: CV *ʔó* 'rice whiskers', SV *yó* 'you pl.', CVC *kón* 'cogon grass', CVS *bá.lay* 'house', CSV *kwí* 'to', SVC *ʔí.yoŋ* 'nose', SVS *mí.yaw* 'rice sifter', CSVC *na.pat.twél* 'carried on a pole', CSVS *dog. gyáw.wi* (a boy's name).

2.3. Specific distribution of phonemes in the syllable.

2.31. Semi-consonants. In the above combinations the only restrictions observed for semi-consonants are those in the pattern CSVS where *w* has not been found before V and *y* has not occurred after V.

2.32. Consonants.

2.32.1. Initial. All consonants occur initial without restrictions, except in syllable patterns with CS. Consonants *f*, *r*, and *ʔ* never occur before S; *n* has not been observed in syllables CSVC and CSV, though it does occur in CSVS. In CSV, *b*, *m*, *s*, and *g* have not been observed; and in CSVC *p* and *n* have not been observed—such non-occurrences are perhaps fortuitous. In CSVS only velars (*k*, *g*, and *ŋ*) have been observed; probably due to the infrequency of examples (only three in the data thus far collected).

2.32.2. Final. Restrictions on consonants occurring after the vowel nucleus may be due partially to limitations observed in word final position. Thus, since syllable patterns SVC and CSVC occur most often word final and since phonemes *f*, *r*, *s*, and *ʔ* never occur word final; these consonants have not been observed after vowels in such patterns except for the one occurrence of *ʔ* in *məyáʔyak* 'trembling with fear'. *p* has not been observed final in SVC nor *p*, *m*, *d*, and *g* in CSVC patterns though this seems fortuitous.

2.33. Vowels. In syllable patterns CV, CVC, SVC, and CSV there are no restrictions. *ə* has not been observed in SV, CVS, or CSVC; *e* has not been observed in CVS; *i* has not been observed in CSVC; and only *a* has occurred in SVS and CSVS.

WORDS

3.1. Definition. A phonological word is a minimum unit of from one to five syllables having a single primary stress, pronounceable in isolation by a naive native speaker. Examples: *ʔaw* 'day', *dáwi* 'left hand', *palátaŋ* 'jaw bone', *salawínit* 'trousers', *natarampóso* 'very wicked'.

3.2. Phoneme restrictions in words.

3.21. Single phonemes. *f, r, ʔ* do not occur in word final position;[11] *r* does not occur in word initial position; and *s* does not usually occur in word final position. In words borrowed from other languages where *s* occurs final, Gaddang speakers have formerly substituted the phoneme *t*. Thus Lunes, Martes, etc., are pronounced *lónit, mártit* by many of the older generation of Gaddangs. However, by those who are bilingual, speaking Ilocano or Tagalog as well as their own language, this habit of replacing *s* with *t* is largely dropped.

3.22. Combinations of phonemes at syllable boundaries. Below is a list of the observed combinations:

ff[12]
pp
bb, br
ss, st
tt, tl
dd
ll, lt, ld, lb
kk
gg
mm, mp, mb
nn, nt, nd, ns
ŋŋ, ŋk, ŋg
ts, rd, rs, rp
ʔb, ʔd, ʔm, ʔn, ʔg, ʔl

The following observations may be noted from this list: (*1*) Except for the clusters *br, lb, rp,* and those involving *ʔ* all clusters are homorganic. Clusters *br, lb,* and *rp,* have been observed only once each in the data thus far collected, and those involving *br* and *lb* in Ilocano loan words: *lébro* 'book', *pólbos* 'powder' and *matárpiŋ* 'slanting rain'. (*2*) There are no clusters of a voiced stop plus its voiceless counterpart or vice versa. (*3*) Glottal stop has a wide range of occurrence as the first member of a cluster, but never occurs as the second member of a cluster.

[11] *d* final becomes *r* when suffixed with a V initial morpheme. Thus *matótod* 'will sit' + *-in* 'now' > *matotorín* 'is sitting'. *b* has this same relationship to *f*, e.g. *tátlib* 'pass by' + *-an* 'verbal affix' > *tatlifán* 'Pass by!'.

[12] Though phonetically long in fast pronunciation, we have called such sequences geminate clusters for the following reasons: (*1*) there are sequences of unlike consonants occurring across syllable boundaries; (*2*) economy of phonemes; and (*3*) when pronounced syllable by syllable these clusters are made up of re-articulated phonemes.

4. Notes on practical orthography. *(1)* Since the sequence *ng* never occurs within words and following general practice in Philippine languages, *ng* will be written in place of /ŋ/. *(2)* In order to conform to the pattern of the National Language, Tagalog, glottal stop is not written word initial or intervocalically. Before consonants or semi-consonants it is written with a grave accent (\`). *(3)* Stress is indicated only where two words would be identical otherwise.

5. A sample text written with the suggested orthography.

ORONG ANI OTA

Snail and Deer

1. *wara kano orong ani ota.*
   is said snail and deer
2. *orong kong kano i ota.*
   snail said the deer
3. *no anggam mo mafot eta si malayyaw.*
   if like you race we running
4. *on kong kano i orong.*
   yes said the snail
5. *gabwat i orong nang nga kano inabiba ino*
   got up the snail went he said contact
   bolon ira a orong.
   friends they snail
6. *ikayo kona kano kasit orong.*
   you pl. he said other snail
7. *ay ino orong kong kaddi ota.*
   snail will say deer
8. *iyawataw ama ota kondaw kong kano i orong*
   I'm here father deer say-you said the snail
   so bolon ira.
   to friend they
9. *wara kano so nabalinin i orong nanarato so*
   is said finished the snail scheming
   bolon ira ay inangin se kwi ota.
   friend they went-now to deer
10. *nekwara kanon ino malayyaw.*
    began said running
11. *waso mekwakag kano so tallyok orong konaman kano.*
    when said bend in river snail said
12. *woy kong kano orong kiyad kano si amena*
    woy said snail until said not-he
    nafonaw ota.
    dizzy deer
13. *wara kano so nafonawin natayyin ota.*
    is said dizzy-now died-now deer

FREE TRANSLATION

Once upon a time there was a snail and a deer. "Snail," said the deer. "If you want to let's race by running."

"Yes," said the snail. The snail left to go to his snail friends. "You snails," said the snail; "When any of you hear the deer shout, 'Snail,' you answer 'here I am father deer'."

When the snail was finished planning with his friends, he returned to the deer and the race began. Whenever the deer came to a bend in the river, he called, "Snail."

"Woy," one of the snails would answer. The deer kept running until he became dizzy and died.

A PRELIMINARY REPORT ON THE EFFECT OF pH ON THE RATE OF SETTLING OF CASSAVA STARCH IN AQUEOUS SUSPENSION

By F. A. SOLIVEN and E. BONECILIO
National Institute of Science and Technology, Manila

THREE TEXT FIGURES

Cassava starch and cassava flour are manufactured from the roots of manioc or cassava plant (*Manihot utilissima* L.). Cassava starch (tapioca) is extensively used in the paper, textile, and match industries; in making dextrin, adhesives for plywood, and veneer; and in laundry and other industries that use starch as the principal raw material; not to mention its use in the food industries.

In the Philippines, cassava flour and cassava starch are used mainly in food preparations, mostly as substitutes for wheat flour, rice flour, and corn starch in the home and the different local industries. Due to their inherent properties and limitations, the use of the flour and the starch in bread dough blending is still on a comparatively very low level, and some bakery owners even shun the idea of using either product in making bread. Ordinary bread, such as a loaf containing even ten per cent of cassava flour in the dough, suffers about eight per cent reduction in volume with no appreciable change in quality. There is, therefore, a need for reconstituting the cassava flour to increase the amount in the blend. When this is done and the cost price of the material is kept down on a competitive basis, no official compulsion will be necessary to make bakers use cassava flour in bread making. In experiments conducted at the Bread Research Institute, Sydney, Australia, the senior author used a blend of 20 per cent of locally produced cassava flour and/or starch and 80 per cent West Australian wheat flour and produced a bread equal in quality and volume to the 100 per cent wheat flour.[1]

Cassava flour and cassava starch are very versatile substitutes for many food preparations in which wheat flour and/or industrial starch is the principal base. This emphasizes the

[1] Details of the process which are still under advisement will be covered by an article now under preparation by the senior author and P. H. Quinitio.

growing importance of cassava as a food source and of its role in our economic development. Any improvement in the mode of its manufacture or processing leading to the reduction of the cost of unit operation without affecting its quality is doubtlessly most welcome.

The commercial method of preparing tapioca in some South American countries may be described as follows: [2]

The roots are washed and the skin and cortex are removed at the same time. The roots are next ground in a series of mills, which includes the hammer-mill—the type most commonly used. The disintegrated root slurry is passed through a grater retaining plate screen openings or slots. The starch is then pumped to brush sieves where the brushes and sprays of water force the starch milk through openings while the pulp is pushed to the discharge-end of the sieve. These brush sieves have been replaced by shaker sieves in the more modern mills.

The pulp is removed and reground or regrated in graters similar to the first, but with retaining or screen plates having smaller holes or slots, and is passed through the second extraction sieve and the starch suspension collected together with the washings from the resultant pulp. The pulp released by this process is normally thrown to the sewer or delivered to the feed department for recovery. The dried pulp is used for animal feed.

The combined starch milk from the extraction sieves is then passed through a refining sieve and the extract is diluted up to 3° to 5° Baume with water. The diluted starch milk is pumped into the settling tanks or vats.

In the vat setup, there may be one to four grater or first protein-water vats which receive the starch milk and protein water from the grater extraction sieves; three to four starch concentration and wash vats; a final wash vat about half the size of the first grater vat; and two settlers or filter-storage vats about the size of the wash vat. The vat layout may be so arranged as to include a recovery trough or vat depending on the volume of roots to be handled during the day.

During a period of eight to ten hours, white starch settles at the bottom of the vats as a heavy layer. The gray suspension or supernatant liquor or protein No. 1, as it is generally called, is drawn off and thrown away.

[2] Brautlecht, C. A. Starch, its Sources, Production and Uses. New York, Reinhold Publishing Corporation, 1953.

The separated starch in the grater vats is resuspended by covering the starch layer with water six to eight inches deep or a volume of water about two to three times that of the volume of starch; then the mixture is agitated and pumped into the wash vat. Enough water is then added so as to fill the vat and at the same time to attain the required density. The starch is again allowed to settle for several hours, ranging from eight to twelve, and the supernatant liquid again drained off as above.

The brown-starch layer over the white-starch layer is scraped and gently slushed off into a sump and pumped into the brown-starch vat or recovery trough.

The starch is further washed with water and the settling process repeated. The washed starch is next pumped into a settler in the dry-house to remove as much water as possible before the starch is finally dried to the required moisture level.

The accumulated brown starch in the brown-starch vat is again washed in the usual way to allow the remaining white starch to settle. The construction of this vat is slightly different from the other vats in that it is provided with a series of outlet valves permitting water protein No. 4 and sludge to flow out into the factory sewer. The small amount of white starch recovered from the brown vat, after resuspension in water, is mixed with the once-washed starch in the wash vat.

The starch in aqueous suspension in the settler of the dry-house is allowed to stand for at least ten hours or preferably overnight. The water is again drained off and the surface cleaned in the usual way. The starch is then ready for final drying.

With modern advances in engineering, a centrifuge or rotary filter may be used instead of vats or settling tables. The suspended starch is passed through this contrivance and the starch is recovered with about 30 to 45 per cent moisture. The product is then ready for drying either in the drying kiln or through a cyclone dryer.

In the Philippines, the process of manufacturing starch, as described by Torres,[3] makes use of the ordinary starch table. We are informed that the cassava mills in Mindanao, on the other hand, use the vat system as described above. Our factories, however, produce more flour than starch.

[3] Philip. Eng. Jour. 4 (1953–54 184–186.

To arrive at a sound basis for modifying existing methods of manufacture, certain basic studies should be undertaken. The writers are not aware of any recorded study along the line of the present report. This report is part of projected studies in a long-range program dealing with cassava flour and cassava starch launched by the Food Technology Division, National Institute of Science and Technology.

MATERIALS AND METHODS

Cassava roots.—The roots used in this study were all purchased from the markets in Manila and Pasay City, and were in most cases over two days old when brought to the laboratory.

Preparation of the roots.—The skin and cortex of the roots were removed and the peeled roots were thoroughly washed to free them from dirt and other foreign materials. The cleaned and decorticated roots were next passed through an ordinary meat grinder.

Water was added to the grated roots so as to give the material a certain degree of fluidity, and the mixture passed through a colloid mill for a period of one hour. The slurry was next passed through a 120-mesh and the filtrate was used in this study. The filtrate consisted of starch and non-protein fractions in suspension and solution, respectively.

Preparation of reagents.—The alkali and acid used for correcting the pH of the slurry were prepared by diluting an ordinary v. s. 3N solution with distilled water.

Chlorine water was prepared by saturating chilled distilled water with chlorine gas from an ordinary liquid chlorine tank.[4]

Sulfur dioxide water was prepared by saturating chilled distilled water with sulfur dioxide gas. The gas was generated by the action of sulfuric acid on metallic copper.

Salt solutions were prepared by dissolving weighed solute in distilled water and adjusting the pH later.

Determination of total solids.—These 10-mls aliquot portions of the well-mixed slurry were measured and transferred into a tared porcelain crucible and weighed. The crucible and its content were dried to constant weight in an ordinary Frease electric oven. From the weight of the residue, the concentration per unit volume was calculated. The concentration of the solid in the slurry as used in these trials was between 0.04 to 0.15 gram per cubic centimeter.

[4] The liquid chlorine was very kindly supplied free of charge by Superior Gas and Equipment Co. through Mr. Jose Borromeo.

The pH of the solution.—The pH of any of the solutions used in this study was determined with the use of an ordinary battery-run Beckman pH meter.

Determination of the rate of settling.—The rate of settling of the starch in the slurry was determined by reckoning the volume of the clear liquid at a given specified time. This was carried out as follows:

Several 25-mls acid burettes were filled with the well-mixed slurry to the zero mark. The pH of the slurry was, however, previously determined. Then at intervals the volume of the clear liquid in the burette was read and recorded. Clearness of the supernatant liquid was reckoned when a dot of ink about ⅛ of an inch in diameter could be seen through the container. For bigger volumes of the slurry, several 500-mls graduated cylinders were used instead of the burettes and sedimentation rates were recorded in similar manner. The data obtained with the use of 500-mls cylinders, however, are not included in this paper.

RESULTS AND DISCUSSION

The results obtained in this investigation are shown in Tables 1 to 6. These and Figs. 1 to 3 represent data obtained with the use of 25-mls acid burettes.

The reaction of freshly harvested cassava roots was on the average neutral. A slurry, however, from a day- or two-day-old cassava root was found to have a pH of from 6.4 to 6.9 indicating a slight shift toward the acid side. All roots used in this study were in most cases two or more days old. Thus, the original reaction of the medium used in this study was to start with the acid of the pH scale.

To find the effect of pH on the rate of settling of cassava starch, a number of trials were run with the use of acid, alkali, and salt in aqueous solutions. With the addition of a small amount of 0.3N solution of NaOH, KOH and NH_4OH to the slurry, it was found that part of the starch in suspension was gelatinized. The gelatinization was more pronounced when the temperature was slightly raised over the normal temperature in the Philippines. We were, therefore, prone to believe that alkali had a negative effect on the speed of sedimentation of starch granules. Hence, further trials on the use of these chemicals were not done.

The use of salts of strong acids and strong bases, such as NaCl, KCl, Na_2SO_4 and KNO_3 of varying concentrations ranging from 0.1 to 10 per cent, was tried. A slight increase in the rate of sedimentation was noted starting at 2 per cent level. The settled starch, however, carried with it some of the solute as evidenced by the taste of the dried starch. Hence, for practical purposes, the addition of any of these salts negatively affects the quality of the resulting product.

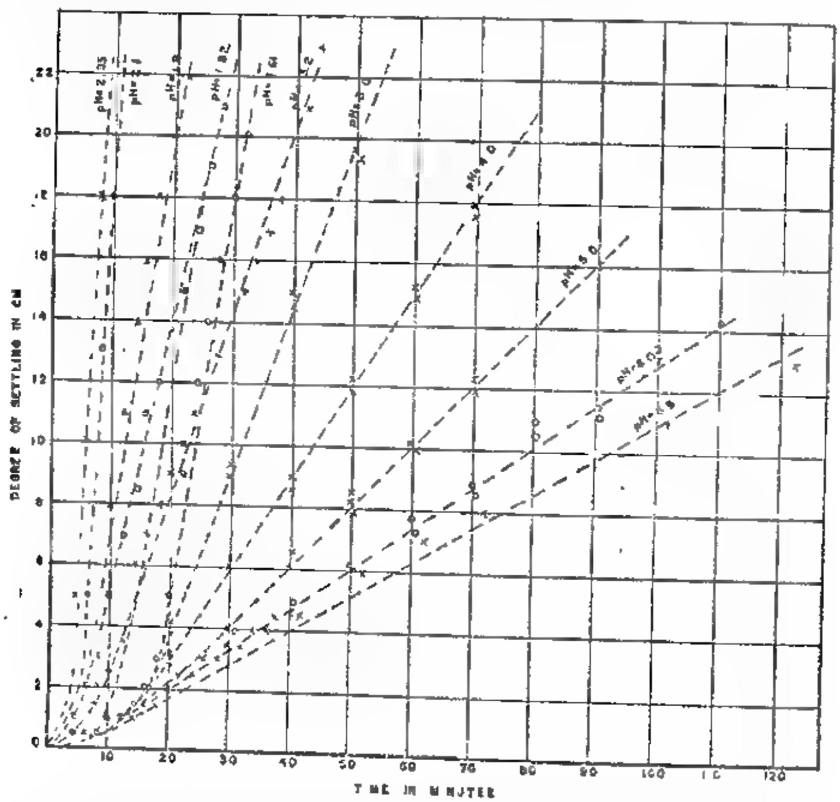


FIG. 1. Rate of sedimentation of cassava at different pH's.

Salts of strong acids and weak bases, and weak acids and bases gave apparently identical results with the salts of strong acids and strong bases. On the other hand, salts of strong bases and weak acids produced also partial gelatinization of some of the starch. When salts of strong acids and weak bases

were again tried, no gelatinization of the starch even at higher temperature took place, but the rate of sedimentation was almost identical with that of the control except at high concentrations. These showed that the rate of sedimentation was greatly influenced by the reaction of the medium as affected by the hydrolysis of the solute.

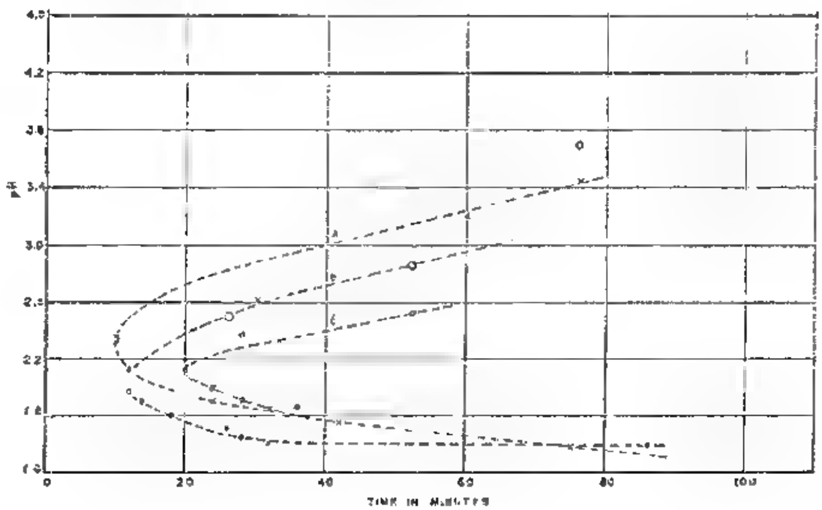


FIG. 2. Sedimentation of cassava starch showing pH's plotted against time.

When the salts were replaced with acids, such as NHO_3, KCl, and H_2SO_4, a faster rate of sedimentation was noted. Aqueous solutions of gases, such as NO_2, SO_2 and Cl_2, were also tried with equal degree of success. The dried starch was pearl white and did not have the taste of the original gas used; hence, there was quality in the product was increased. It was apparent that from the standpoint of color, the effect of use of the above gases especially SO_2 is superior to that of the use of any of the acids. The results herein presented were obtained with the use of SO_2 gas. The tables herein show that the greatest rate of settling took place at pH's between 1.9 to 2.35.

With the use of a slurry with a concentration of 0.0336 gram per cc in fresh cassava roots, 0.0532 gram per cc in two-day-old and four-day-frozen cassava roots, trial runs were done at different pH's. Figure 2 shows the results obtained by plotting pH against time in minutes. As indicated in this figure, the best pH is around 2.0.

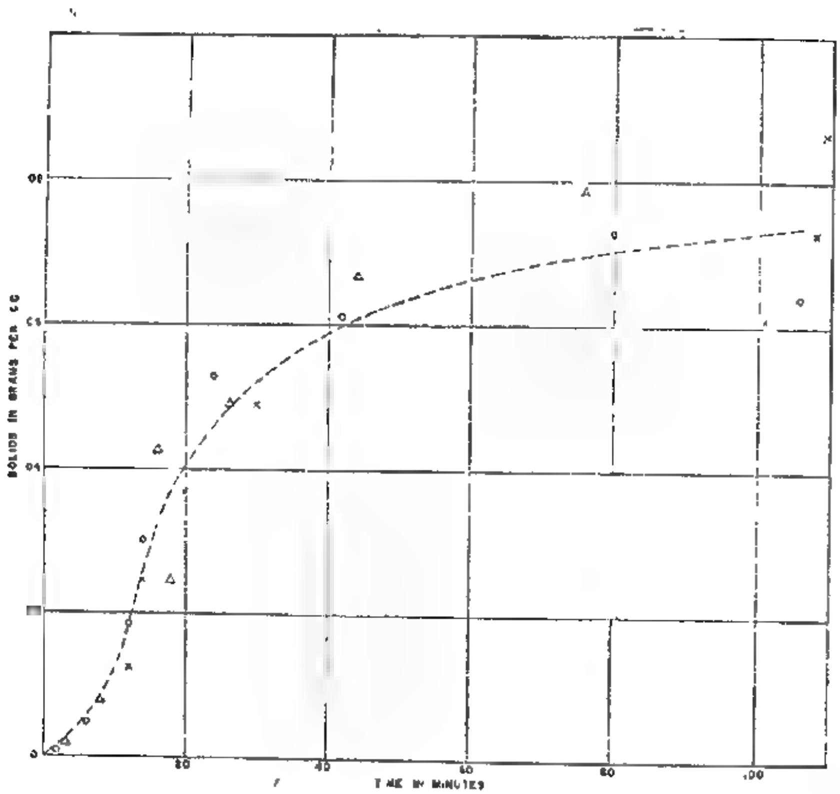


FIG. 3. Rate of sedimentation of cassava starch at different total solids at pH 2.

By plotting concentration of solids against the time of settling, Fig. 3 was derived. As this figure shows, the concentration of starch per unit volume bears an influence on the rate of sedimentation; the best concentration is below 0.06 gram per cubic centimeter. At higher concentration, the rate of settling is comparatively slower. For practical purposes, therefore, it may be said that the slurry should be diluted with enough water so that the resulting suspension would be around 0.06 gram solid per cc.

TABLE 1.—*Rate of settling of starch with varying volumes of sulfur dioxide water using freshly prepared cassava starch slurry 0.0366 gm/cc.*

	Trials	Control	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
Condition	Volume of:	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*
	H_2SO_3 solution	0.0	60.0	40.0	30.0	25.0	20.0	15.0	10.0	5.0	4.0	2.5	1.0	0.5
	Starch solution	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	80.0	30.0
	H_2O	60.0	10.0	20.0	30.0	35.0	40.0	45.0	50.0	55.0	56.0	57.0	59.0	59.5
	pH	6.9	1.5	1.61	1.7	1.75	1.82	1.9	2.1	2.35	2.32	2.61	3.2	3.44
Degree of settling	*Minutes*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.0	8.0	1.0	0.5	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.0	10.0	11.0	2.0	1.0	0.5
	8	0.5	0.5	0.5	0.5	0.5	0.5	2.0	13.0	18.0	14.0	3.0	1.5	1.5
	10	1.0	1.0	1.0	1.0	1.0	2.0	8.0	18.0	clear	19.0	5.0	2.5	2.0
	12	1.0	1.0	1.5	1.0	1.0	3.0	11.0	clear		clear	7.0	3.5	3.0
	14	1.0	1.5	2.0	1.5	1.5	5.0	14.0				9.0	6.0	4.0
	16	1.5	2.0	3.0	2.0	2.0	7.0	16.0				11.0	7.0	5.0
	18	1.5	2.5	4.0	3.0	3.0	10.0	18.0				12.0	8.0	6.0
	20	2.0	3.0	5.0	5.0	5.0	13.0	20.0				14.0	9.0	7.0
	22	2.5	3.5	6.0	8.0	9.0	16.0	22.0				15.0	10.0	8.0
	24	2.5	3.5	7.0	10.0	12.0	18.0	clear				17.0	11.0	9.0
	26	3.0	4.0	9.0	12.0	14.0	20.0					19.0	12.0	10.0
	28	3.0	5.0	11.0	13.0	16.0	23.0					21.0	13.0	11.0
	30	3.5	6.0	14.0	14.0	18.0	clear					23.0	14.0	12.0
	32	3.5	7.0	18.0	15.0	20.0						24.0	15.0	13.0
	34	4.0	8.0	clear	16.0	21.0						clear	16.0	14.0
	36	4.0	9.0		17.0	22.0							17.0	15.0
	38	4.5	10.0		18.0	24.0							18.0	16.0
	42	4.5	11.0		19.0	clear							21.0	18.0
	52	6.0	14.0		clear								clear	21.0
	62	7.0	17.0											24.0
	72	8.0	clear											clear
	112	13.0												
	162	18.0												
	210	clear												

TABLE 2.—*Rate of settling of starch with varying volumes of sulfur dioxide water using a two-day-old cassava slurry, frozen 0.0866 gm/cc.*

	Trials	Control	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
Condition	Volume of:	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*
	H_2SO_3 solution	0.0	50.0	40.0	30.0	25.0	20.0	15.0	10.0	5.0	4.0	2.5	1.0
	Starch solution	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	H_2O	60.0	10.0	20.0	30.0	35.0	40.0	45.0	50.0	55.0	56.0	57.5	59.0
	pH	6.8	7.6	1.65	1.7	1.8	1.9	1.95	2.1	2.5	2.35	2.85	3.7
Degree of settling	*Minutes*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
	2		0	0	------	------	------	------	------	------	2.0	1.0	0.5
	4	0	0	0.5	1.0	2.0	5.0	6.0	6.0	2.0	4.0	2.0	1.0
	6	------	0.5	1.0	------	------	------	------	------	------	5.0	3.0	1.5
	8	0	1.0	1.5	4.0	7.0	11.0	13.0	13.0	6.0	7.0	4.0	2.0
	10	0.5	1.5	2.0	6.0	10.0	17.0	19.0	19.0	9.0	8.0	5.0	2.5
	12	0.5	2.0	2.5	8.0	13.0	21.0	clear	clear	11.0	9.0	6.0	3.0
	14	0.5	4.0	4.0	10.0	16.0	clear	------	------	13.0	11.0	7.0	5.0
	16	1.0	5.0	6.0	13.0	20.0	------	------	------	15.0	13.0	8.0	6.0
	18	1.0	6.0	9.0	15.0	clear	------	------	------	17.0	15.0	10.0	7.0
	20	1.0	7.0	14.0	18.0	------	------	------	------	19.0	17.0	11.0	7.5
	22	1.5	8.0	17.0	23.0	------	------	------	------	23.0	19.0	12.0	8.0
	24	1.5	9.0	21.0	clear	------	------	------	------	clear	21.0	13.0	9.0
	26	------	10.0	23.0	------	------	------	------	------	------	23.0	15.0	9.5
	30	2.0	11.0	clear	------	------	------	------	------	------	clear	16.0	10.0
	34	------	12.0	------	------	------	------	------	------	------	------	17.0	11.0
	38	------	13.0	------	------	------	------	------	------	------	------	18.0	12.0
	44	------	14.0	------	------	------	------	------	------	------	------	20.0	14.0
	50	3.0	18.0	------	------	------	------	------	------	------	------	23.0	17.0
	58	------	20.0	------	------	------	------	------	------	------	------	clear	20.0
	74	7.0	clear	------	------	------	------	------	------	------	------	------	clear
	94	10.0	------	------	------	------	------	------	------	------	------	------	------
	114	12.0	------	------	------	------	------	------	------	------	------	------	------
	134	15.0	------	------	------	------	------	------	------	------	------	------	------
	154	20.0	------	------	------	------	------	------	------	------	------	------	------
	164	clear	------	------	------	------	------	------	------	------	------	------	------

85718——8

TABLE 8.—*Rate of settling of starch with varying volumes of sulfur dioxide water using four-day-old cassava starch slurry 0.0532 gm/cc.*

	Trials	Control	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Condition	Volume of:	*cc*	[illegible]	*cc*	*cc*	*cc*	*cc*	*cc*
	H_2SO_3 solution	0		25.0	20.0	15.0	10.0	5.0
	Starch solution	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	H_2O	60.0	30.0	35.0	40.0	45.0	50.0	55.0
	pH	6.3	1.7	1.85	—	1.9	2.0	2.5
Degree of settling	*Minutes*	*cm*	[illegible]	*cm*	*cm*	*cm*	*cm*	*cm*
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	1.0	8.0	1.0
	12	0.5	0.5	0.5	0.5	7.0	14.0	3.0
	16	0.5	1.0	1.5	2.0	13.0	19.0	5.0
	20	1.0	1.5	2.5	10.0	18.0	clear	7.0
	24	1.0	2.5	7.0	18.0	clear	—	9.0
	28	1.0	4.0	14.0	clear	—	—	12.0
	32	1.0	6.0	20.0	—	—	—	14.0
	36	1.5	12.0	clear	—	—	—	16 0
	40	1.5	16.0	—	—	—	—	18 0
	44	2.0	20.0	—	—	—	—	21.0
	48	2.0	23.0	—	—	—	—	23.0
	52	2.0	clear	—	—	—	—	clear
	60	3.0	—	—	—	—	—	—
	80	4.0	—	—	—	—	—	—
	100	5.0	—	—	—	—	—	—
	120	6.0	—	—	—	—	—	—
	140	7.0	—	—	—	—	—	—
	160	8.0	—	—	—	—	—	—
	180	9.0	—	—	—	—	—	—
	200	10.0	—	—	—	—	—	—
	220	11.0	—	—	—	—	—	—
	240	11.0	—	—	—	—	—	—

TABLE 4.—*Relation of solid with respect to time of settling, at constant pH 2.0 to 2.4 and with use of fresh cassava starch slurry.*

	Trials	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. [illegible]	No. 10	No. 11	No. 12	No. 13
Condition	Volumes of:	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*
	H_2SO_4 solution	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10 0	10.0	10.0	[illegible]	10.0	10.0
	Starch solution	80.0	70.0	60.0	60.0	55.0	50.0	45 0	40.0	35.0	30.0	25.0	20.0	15.0
	H_2SO_4	0.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65 0
	pH	2.3	2.4	2.1	2.25	2.05	2.3	2.05	2.15	2.0	2.10	2.0	2.0	2.0
	gm/cc in solution	0.0979	0.0857	0.0796	0.0735	0.0673	0.0611	0.0551	0.0490	0.0429	0.0367	0.0306	0.0245	0.0185
Degree of settling	*Minutes*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	1.0	1 0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	6	1.5	1.5	1.5	1.5	2.0	2.0	4.0	2.0	5.0	2.0	6.0	2.0	8.0
	8	2.0	2.0	2.0	2.0	3.0	3.0	8.0	3.0	10.0	3.0	10.0	3.0	12.0
	10	2.0	3.0	2.5	3.0	5.0	5.0	10.0	5.0	14.0	6.0	16.0	6.0	21.0
	12	2.5	3.5	3.0	4.0	6.0	6.0	12.0	7.0	16 0	9.0	21.0	10.0	clear
	14	2.5	3 5	3.5	4.5	7.0	7.0	14.0	9 0	19.0	13.0	clear	15.0	----
	16	3.0	4.0	4.0	5.0	8.0	8.0	15.0	11 0	clear	16.0	----	19.0	----
	18	3.5	4.5	5.0	6.0	10.0	9.0	17.0	14.0	----	21.0	----	clear	----
	20	4.0	5.0	6.0	6.5	12.0	10.0	clear	16.0	----	clear	----	----	----
	22	4.0	5.0	7.0	7.0	14.0	11.0	----	18.0	----	----	----	----	----
	24	4.5	5.5	8.0	8.0	16.0	12.0	----	20.0	----	----	----	----	----
	26	4.5	6.0	9.5	9.0	18.0	13 0	----	clear	----	----	----	----	----
	28	5.0	6.5	11 0	10.0	20.0	14.0	----	----	----	----	----	----	----
	30	5.0	7.0	12.5	11.0	clear	15.0	----	----	----	----	----	----	----
	38	6.0	9.0	20.0	14.0	----	20.0	----	----	----	----	----	----	----
	44	7.0	9.5	clear	15.5	----	clear	----	----	----	----	----	----	----
	56	8.5	11.5	----	19.0	----	----	----	----	----	----	----	----	----
	68	10.0	16.0	----	clear	----	----	----	----	----	----	----	----	----
	103	12.5	20 0	----	----	----	----	----	----	----	----	----	----	----
	143	15.0	clear	----	----	----	----	----	----	----	----	----	----	----
	203	18.0	----	----	----	----	----	----	----	----	----	----	----	----
	263	clear	----	----	----	----	----	----	----	----	----	----	----	----

TABLE 5.—*Rate of settling of starch from a one-day-old cassava starch slurry at constant pH and varying concentrations.*

	Trials	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Condition	Volume of:	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*
	H_2SO_4 solution	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	Starch solution	70.0	60.0	50.0	40.0	30.0	20.0	10.0
	H_2O	10.0	20.0	30.0	40.0	50.0	60.0	70.0
	pH	2.0	2.0	2.20	2.0	2.0	2.0	1.95
	gm/cc	0.0857	0.0735	0.0611	0.0490	0.0367	0.0245	0.0122
Degree of settling	*Minutes*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
	4	0.0	0.5	1.0	2.5	3.0	4.0	4.0
	6	0.5	1.0	1.5	4.5	6.0	8.0	8.0
	8	0.5	1.0	1.5	6.0	8.0	14.0	16.0
	10	0.5	1.5	2.0	8.0	11.0	18.0	22.0
	12	1.0	2.0	2.5	9.5	13.0	21.0	clear
	14	1.0	2.5	3.0	11.0	15.0	clear	----------
	16	1.0	3.0	3.5	13.0	18.0	----------	----------
	18	1.5	3.5	4.0	14.5	21.0	----------	----------
	20	1.5	4.0	4.5	16.0	clear	----------	----------
	24	2.0	5.0	5.5	19.5	----------	----------	----------
	30	3.0	6.5	7.0	clear	----------	----------	----------
	34	3.5	7.5	8.0	----------	----------	----------	----------
	42	4.5	9.5	10.0	----------	----------	----------	----------
	50	5.0	10.5	11.5	----------	----------	----------	----------
	58	6.0	11.5	13.0	----------	----------	----------	----------
	66	7.0	12.5	14.5	----------	----------	----------	----------
	74	8.0	14.0	16.0	----------	----------	----------	----------
	82	9.5	15.5	17.5	----------	----------	----------	----------
	90	11.0	17.5	20.0	----------	----------	----------	----------
	106	14.5	22.0	clear	----------	----------	----------	----------
	114	16.0	clear	----------	----------	----------	----------	----------
	130	clear	----------	----------	----------	----------	----------	----------

TABLE 6.—*Rate of settling of starch from a three-day-old cassava starch slurry at constant pH and varying concentrations.*

	Trials	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13
Condition	Volumes of:	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*	*cc*
	H_2SO_4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10 0	10.0	10.0
	Starch solution	70.0	65.0	60.0	55.0	50.0	45.0	40.0	30.0	20.0	10.0	8.0	4.0	2.0
	pH	2.1	2.1	1.2	2.1	2.0	2.1	2.0	2.0	2.0	2.0	2.05	2.0	2.0
	gm/cc in solution	0.0694	0.0644	0.0596	0.0545	0.0495	0.0446	0.0396	0.0297	0.0198	0.0099	0.0079	0.0039	0.0020
Degree of settling	*Minutes*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	6.0	12.0
	4	0.0	0.0	0.0	0.5	0.0	1.0	0.0	0.0	0.5	1.0	18.0	10.0	clear
	6	0.0	0.5	0.5	1.0	0.5	2.0	0.5	1.0	1.5	2.5	21.0	clear	
	8	0.5	0.5	0.5	2.0	1.0	3 0	1.5	2.5	3.0	3.6	clear		
	10	0.5	1.0	1.0	3.0	1.5	4.5	3.5	4.5	5.0	6.5			
	12	1.0	1.5	2.0	4.0	3 0	6 0	5.0	8.0	9.0	11.0			
	14	1.0	2.0	3.5	5.0	5.0	7.5	8.0	13.0	15 0	18.0			
	16	1.5		5.0		9.0		13.0	18.0	21.0	clear			
	18	2.0	3.0	6.0	7.0	13.0	0.5	19.0	22.0	clear				
	20	2.5		7.0		15.0		22.0	clear					
	22	3.0	4.6	8.0	9.5	17.0	12.0	clear						
	24	4.5		9.0		20.0								
	26	6.0	6.0	10.5	12.0	23.0	14.5							
	28	7.6		12.5		clear								
	30	10.6		16.0										
	34	15.5	8.5	clear	15.0		20.0							
	42	16.0	10.5		18.0		28.0							
	52	21 5	16.0		21.0		clear							
	56	clear												
	67		19.5		clear									
	117		clear											

CONCLUSIONS

The results provide evidence of the influence of the hydrogen ion concentration of the medium in which the starch granules are suspended on the rate of settling of cassava starch and bring out the following conclusions:

1. At pH range of 1.9 to 2.1, the starch in a slurry containing 0.0366 gram per cubic centimeter may be completely settled in 12 to 14 minutes, and that the rate of settling decreases as the pH is increased or decreased.
2. At constant pH (2.0), the rate of settling of cassava starch is also influenced by the amount of starch per unit volume, the more concentrated the slower is the rate of settling. The concentration of cassava starch for rapid settling has been found to be not greater than 0.06 per cubic centimeter.

ILLUSTRATIONS

TEXT FIGURES

THREE NEW RECORDS FOR THE PHILIPPINE FLORA

By C. G. G. J. VAN STEENIS
Flora Malesiana Foundation, Leyden

Among duplicates of some recent Philippine collections there are three native species which have hitherto not been recorded for the Philippine flora, two of which belong to genera which are unknown from the Philippine archipelago.

Family STYRACACEÆ

Genus BRUINSMIA Boerl. et Koord.

BRUINSMIA STYRACOIDES Boerl. & Koord.

Bruinsmia styracoides BOERL. & KOORD., Natuurk. Tijd. Ned. Ind. 53 (1893) 68; PERKINS, Pflanzenreich 30 (1907) 14, 88; VAN STEENIS, Bull. Jard. Bot. Buitenzorg, sér. (3) 12 (1932) 215, Fl. Mal. (1) 4 (1949) 50, *fig. 1.*

MINDANAO, Zamboanga del Norte, pr. Dikus, altitude 500 m, Charles O. Frake No. 287 = *Philip. Nat. Herb. 36146,* October 10, 1957, tree 10 m high, 10 cm diameter, in secondary growth, fruit green, edible, vern. sulingad (Sub.).

This monotypic genus is endemic in Malaysia; it is widely distributed in the hills and montane rain-forests from Sumatra to New Guinea; it had already been found in North Celebes long ago, and was expected [*l. c.* (1949) 50] to occur in the Philippines. It is as yet also not recorded from the Moluccas. Elsewhere the fruits, which are rather dry-celled capsules, have not been recorded as being edible.

Family GENTIANACEÆ

Genus CANSCORA Lam.

CANSCORA MACROCALYX Miq.

Canscora macrocalyx MIQ., Fl. Ind. Bat. 2 (1857) 558; BACKER, Onkruidfl. Jav. Suikerrietgronden (1931) 488, Atlas *plate 465;* Bekn. Fl. Java (em. ed.) 8 (1949) 4, *fam.* 179.

MINDANAO, Zamboanga del Norte, pr. Nipaan, altitude 50 m, Charles O. Frake No. 455 = *Philip. Nat. Herb. 36800,* November 19, 1957, herb under 50 cm high, with winged stem and calyx, flower white, in second growths, leaves applied as medicine for ulcers, vern. pelesagi (Sub.).

The duplicate which was distributed as cf. *Torenia* sp. exactly matches specimen from Java. The species is hitherto only known from Java and the Lesser Sunda Islands as far as east Timor and there largely confined to areas subject to a dry

season as a small annual herb in grassland and open scrub, often liable to fires, up to c. 400 m. The species is obviously allied to *C. decussata* (Roxb.) R. & S. which ranges from Africa to India, Burma, and Siam.

It differs from that species by wider winged stems, shorter, stronger pedicels, very much broader calyx wings, acuminate long-mucronulate flaccid tip of calyx lobes which often recurves, and somewhat smaller corolla lobes which do not or hardly possess any of peculiar glands found in *C. decussata*. It seems a perfectly distinct species.

I note here that in both species I found two kinds of flowers, one with short styles and another with long styles. It may be that the flowers are protrandrous but there may also occur flower dimorphism. I note further that in both species one stamen is sometimes slightly inserted higher than the three others, but all anthers are of the same size and obviously fertile.

Family LILIACEÆ

Genus GEITONOPLESIUM A. Cunn.

GEITONOPLESIUM CYMOSUM (R. Br.) A. Cunn.

Geitonoplesium cymosum (R. Br.) A. CUNN., Bot. Mag. 59 (1832) Pl. 3131; SCHLITTLER, Ber. Schweiz. Bot. Ges. 61 (1951) 226 (with full synonymy), 239 (distr. map).

Luzuriaga cymosa R. BR., Prod. Fl. Nov. Holl. (1810) 282.

MINDORO, Mt. Yagaw, altitude 450 m, Harold C. Conklin No. 1070 = *Philip. Nat. Herb. 37609*, February 6, 1958, in primary vegetation, a herb, 40 cm high, flowers light colored (not seen in the Leyden duplicate), vern. wili wili bul adlad (Hanunóo).

The genus is a typically Australian-Melanesian one and of South Pacific affinity, radiating towards Malaysia. It is known to occur along the entire eastern fringe of the Australian continent in New Caledonia, Fiji, the Solomon Islands, New Britain, New Guinea, the Lesser Sunda Islands, and the Island of Buru in the Moluccas.

The species is very variable in habit and Dr. Schlittler distinguished a number of varieties and forms, mainly based on habit and leaf-shape.

Some specimens resemble very much *Eustrephus latifolius* R. Br. ex Sims in vegetative characters, but it has short terminal inflorescences, flowers with entire inner tepals, whereas *Eustrephus* has axillary, fascicled flowers with fringed inner tepals.

NOTES ON BURIAL CUSTOMS IN AND NEAR SAGADA MOUNTAIN PROVINCE

By WILHELM G. SOLHEIM II
University of Arizona, Tucson, Arizona

ONE PLATE AND ONE TEXT FIGURE

While visiting in Sagada for a few days in 1954, I was taken to one of the local burial caves. In examining some of the coffins I noted a carved lid on one, held in place with carved pegs. I removed these pegs from the coffin and replaced them with a pair of plain pegs that were lying nearby. The pegs were presented to the National Museum in Manila.

Dr. Eduardo Quisumbing, the Director of the Museum, asked me to write a short note concerning the pegs. As I had only very incomplete information, I wrote to Mr. William Henry Scott, who had offered to collect any information or find the answer to any questions on Mountain Province subjects if it were possible for him to do so. At that time Mr. Scott was an instructor at St. Mary's (High) School, in Sagada. To Mr. Scott I am indebted for a great majority of the information herein presented and I wish to thank him very much.

The cave, called Lumang in Sagada, is situated several hundred meters south and southeast of the town of Sagada. To reach the entrance of the cave it is necessary to make a short but extremely steep descent into a small natural amphitheater situated immediately to the east. The cave, in a limestone cliff, is the result of water action. Beyond the large entrance room it extends back into the hillside in a narrow passage turning to the right and thus out of sight. There is no horizontal floor at the entrance, only a steep embankment sloping up to the right at about 60 degrees as one faces the cave. At the top of this embankment, where it meets the stone wall, and on a narrow ledge running back into the cave, are the wooden coffins. (Plate 1, fig. 1)

The coffins had been placed one atop the other in as many as seven to nine layers, and at the base of the stack the embankment was wide enough to permit the presence of three to four coffins deep. About forty meters to the rear of the

foremost coffin the embankment became an almost sheer stone wall. Here the impressive pyramid of coffins came to a stop. After a short break the coffins continued in single file, placed on a ledge no wider than the width of a single coffin. This ledge extended back out of sight around the bend in the cave. The gap between the two groups of coffins was about five meters wide. Here the rock wall was practically smooth. Below the ledge there was a vertical drop of from 10 to 20 meters, increasing as the ledge disappeared back into the cave. The beginning of this ledge can just be made out in Plate 1, fig. 1, directly above the head of the boy on the left and roughly on a row with the uppermost coffins.

Numerous coffins lay awry probably as a result of earthquakes—at the base of the embankment where they had fallen. One fully extended skeleton lay halfway down the incline. My guides explained that a group of Boy Scouts from Baguio a couple of years before had taken the skeleton out of one of the coffins and had tossed it down the slope. From a distance it appeared to be in remarkably good condition, still articulated.

As is noticeable in Plate 1, fig. 1, the coffins are of two varieties. The more common type is circular or polygonal in cross section, hollowed out from the trunk of a tree. The lid of this type is a horizontal section of the log. In a rectangular hole cut vertically through short protruding tongues at either end of both the coffin body and lid, a wedge-shaped peg firmly holds the lid to the body. The other type of coffin is longer and not as thick. This variety is made from sawn planks nailed together. In the log coffins the burials are tightly flexed while in the plank coffins they lay fully extended.

The carved coffin with its carved pegs was the only one of its kind in sight. Its position was at the back of the great wall of coffins, out of sight in the picture, a short distance from the beginning of the ledge and some five meters below its level. It was one of the variety carved from a single piece of wood, differing in shape only in that it had a larger flat surface on its lid than did the others. On this flat surface and extending unto one beveled side of the lid was carved a zoomorphic design in low relief. The tops of the two pegs were carved in the shape of human figures. All other pegs and coffins seen were plain.

The design cut into the lid was of two tailed animal figures probably lizards facing away from each other (Fig. 1). Except for the head of the right hand figure, the work was done

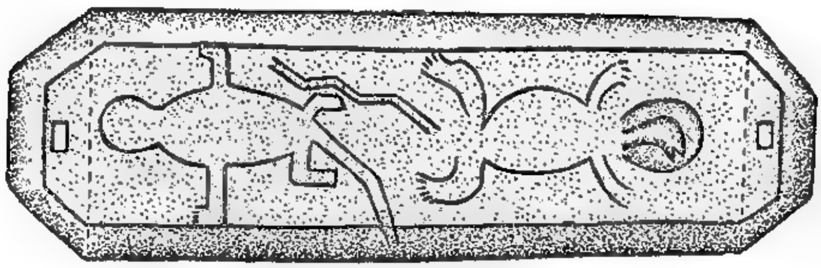


FIG. 1. Sketch of carved coffin lid from Lumang cave.

in outline with a slight bit of rounding from the cuts forming the outline. The head of the right hand figure was carved in negative relief, the oval area surrounding the head being cut out leaving the form of the head standing out. The interior bounding line in the sketch marks the extent of the flat surface. (Fig. 1). Between that and the exterior bounding line was the beveled side of the lid. Beyond the dotted lines at either end of the lid was the tongue in which were the rectangular holes for the pegs. The total length of the lid was 122 cm and its total width was 36 cm.

The pegs, called *tínag tágo* ("like a man," i.e. a statuette) by the two young guides, were in their respective holes so that only the carved figures on their upper ends were visible. The figures were in the characteristic position of the older carved human figures found in the Mountain Province (Plate 1, fig. 2). They were sitting or squatting with their elbows resting on their knees and their arms crossed over their chest. The possibly more common variety of this position with elbows on knees is with the forearms vertical and the head resting in the palms.

I asked my two guides (both boys were native to Sagada) what the significance was of the carved coffin and pegs. They had no idea. I asked them if anyone would mind if I took the carved pegs with me and substitute for them a pair of plain ones which were lying near by. They could see no reason why anyone would be bothered. Asked if this would not be showing disrespect towards the dead they said that no one cared about the dead, except possibly for some of the most recent burials there. They said that the children thereabouts sometimes

would come up there and remove one of the skulls from a coffin and play around with it for a while as if it were a basketball.

The same evening, after substituting plain for carved pegs in the coffin, two locally important men were consulted about the advisability of taking the pegs to Manila and giving them to the National Museum. They were quite certain that no one around there would be disturbed by this action.

The following information came from Mr. Scott:

The carved coffin.—The carved coffin was ordered by Gaongen of Sagada while he was living in Ambainget (between Besao and Sumadel). Gaongen returned to Sagada when he was older and he brought the coffin with him. T., a grandson of Gaongen now 60 to 70 years old, says that he was a small child when his grandfather died. This would mean that Gaongen died about 1900 or earlier and that the coffin had been made sometime before that.

Father P. of Besao says that Sagada is known for carved pegs and lids to coffins, at least in Besao. According to him these carvings show that the occupant was wealthy or respected, or perhaps simply that those who made the coffin could carve well. Both the carved lid and the figure pegs are supposed to have protective influence, but Father P. did not know whether it was the occupant or the survivors who were protected. However, old men in Sagada denied the protective influence, insisting that it was purely decorative.

Attitude on disturbance of coffin.—Fathers P. and B. and two old men from Sagada all agreed that in the pagan belief any harm to the coffin or its occupant would endanger the survivors, presumably because the spirit of the deceased would become angry over the desecration. All agreed that the owners would be concerned and not like it. When pressed on the moral question involved, Father P. at first insisted that what Solheim had done was objectionable not to Igorots generally but to the survivors only, and that, only "if they know." However, direct questioning of the old men established that they thought it "wrong" for Solheim to have taken the carvings to Manila. Father B. said that if the survivors of the occupant of the desecrated coffin discovered the loss, they would pray and make sacrifices so that the misfortune would befall the perpetrator of the deed rather than themselves.

Additional elaboration by Father P. on fear of disturbing coffins was that only the modern educated generations do not fear touching the dead. As a boy he had been told that if he looked at a corpse in a coffin he would go blind. T. said that there was a superstition that for one who buried, for instance, his grandfather, the grandfather's coffin and the immediate vicinity would thenceforth be "dangerous" to him. The removal and scattering of the remains from coffins would be very untypical of *illi* educated students or children who under any circumstance would be deathly afraid of toying with the dead.

Kuan M. tells the following story to illustrate why the corpse must be left alone after burial: Basálang of Bagnen came and married and settled and had children in Sagada. When he died his father sent his brothers to bring his body back to Bagnen but the Sagada-born sons of Basálang would not give it up. They buried it locally in a cave or on a rock ledge. The brothers of Basálang were chided by their angry father for returning empty-handed and he sent them back again to get the corpse. The brothers went in the dark of night, found the coffin and opened it to get the body but found the eyes open and staring at them. Quickly they closed the coffin, rebound it with rattan, and carried the whole thing to Bagnen. All the brothers died, one by one. Thus, one should never open coffins or otherwise expose oneself to the stare of a corpse.

General information on coffins.—Concerning the two types of coffins, the two old men say that the board coffins came in during their lifetime with the introduction of tools by Japanese carpenters whom the missionaries had brought in. An unlikely version presented by a younger man was that the board ones were quickly made when a sudden death did not allow time for the preparation of the one-log kind. Father P. said that before the plank coffins came into use, if a coffin were needed quickly before a one-log coffin could be prepared, an already hollowed-out rice-mortar log was used, at least in Besao.

The one-log coffin may still be in use. One such coffin in a group of five at a ledge site has carved on its side "Lacay Gangowan age 45 years B . . ." (rest of inscription obscured by stone which wedges the coffin into the ledge). Patricio T. was in 2nd grade (1948–49) when this man died, and although Patricio did not accompany the burial, he had seen the coffin

before. The coffin had been prepared by Gangowan himself in his youth. Though of the old style, the lid had been nailed on rather than pegged.

Burial customs.—Before burial the corpse is tightly flexed and wrapped in a new *kálgo* (blanket for the dead). To flex the body is very difficult. For an adult body it often requires four men struggling and straining to get the arms up with the hands alongside the chin and the knees close to the chin. When it is forced into this position, it is then bound tight with rattan. Kuan M., who gave this information, believes that no bones are broken in the process. For the full-length burial of today, the body is untied after it is brought to the grave site and there is no difficulty in straightening it out.

The preparation of the body can be done by any of the family males, including the person's own sons. However, men still young enough to have young children or to expect more children, should not handle the corpse, as this would be bad for the young or unborn children.

When it is time for the burial the coffin is taken empty to its permanent location. The body comes later, being "tossed like a basketball" among the pallbearers. Father P. has developed his own explanation for this action saying that it is because the people are always afraid of the dead; "In some places nobody will even touch the dead." No other explanation has been found. Old men thought that it was good fortune to touch the corpse, "even when pus gets on you from it, don't wipe it off, it's good luck."

Ankileng, a barrio just south of Sagada, lacks convenient caves, so burials are under ground in stone "rooms" or artificial caves. Scott was shown the entrance to one of these on the west side of the barrio overlooking the stream and beneath a camote patch. For the opening to be seen, underbrush had to be pulled aside. The interior was described as a large room (presumably 7 by 7 meters) with a stone floor. Here the coffins were placed in rows side by side. The bodies were reported to be in the coffins full length, not doubled up, but Scott questions this statement. This cave was reported to be the private property of one family. Other such caves were supposed to be under *dap-ays* ("ward center," a ceremonial platform equivalent to the Bontok *ato*) or other places. The burial cave under the *dap-ay* does not belong to one family and can apparently be used by anyone. This cave has stones which

can be removed for the entrance. Two informants in Sagada scoffed at the idea of everyone having their own family cave and insisted that the common people just buried under houses or near them. Ankileng people say that they do not toss the bodies around on the way to the grave. One old man explained the non-use of the distant cave was due to the fact that on the way to caves the people might see rats or snakes or other bad omens, so they bury the dead inside the barrio to avoid these.

In Bogang, midway between Sagada and Ankileng, if a person dies during or near rice planting time or during the growing of the rice, the body must be taken to a cave. The caves used are not close to Sagada but near Latipan or farther south. On the way to the caves the bodies are tossed from shoulder to shoulder in the Sagada way. The body of a person dying during plowing or after harvest however is buried locally in the ground.

Jar burial was in use for children. A quotation by Dr. Fred Eggan from Barton's "Further Notes on Sagada Burial Customs and Beliefs" page 32 (unpublished) states "Father Vincent Gowen tells of a case in which the child's parents came to him and asked him to permit the child to be given the last rites in a jar. Though he considers himself and is considered a liberal man, this was rather more than he could agree to. He therefore told them that if they wanted the child to receive Christian burial, they would have to bring him in a coffin. The parents were dead set on jar burial and asked if there would be any objection to transferring the corpse to the jar at the campo santo. At the campo santo the body of the child was cut up (which almost finished Father Gowen) and transferred to the jar, which was said to be a very old one."

Burial of the widow Da-on—July 12, 1954: On the 8th of July at 0915 a coffin was carried up from Demang past the back of the school building and up the hill opposite the main entrance toward Calvary to a ledge site below and east of Calvary. At 1320 the body followed in a small bundle, being tossed about from person to person. This was the widow Da-on, who died the night of July 6 of sickness.

August 1, 1954: Went this morning to see the coffin with Patricio T. who had accompanied the body of Da-on to its burial site in Bao-éng. Bao-éng is the valley immediately south of Latang. The coffin is about 10 meters higher than the path, the last 3 meters below the coffin being a limestone wall. On

the same ledge and slightly to the west of the new coffin are 5 older coffins.

Da-on's coffin is the full-length style, $160 \times 28 \times 28$ cm excluding the lid. Da-on was very old at the time of her death. She presumably died of old age, but accompanied by dysentery (Kuan M. says that this is the usual case with old people's death). The coffin had been placed on the ledge in the morning. That afternoon the body was brought up accompanied by about 30 people, including sons of Da-on who, however, had to stop on the path and not accompany the body to the coffin, only rejoining the party on its return (grandchildren do not suffer this tabu). On top of the coffin was a paper-wrapped *tapis* (wrap-around skirt) for the dead (made new for the dead only), in case the spirit of the dead woman "wants to come into the town."

August 10, 1954: On Saturday morning went, with Patricio T. and Leonard A. as interpreter, to Bilig, Demang, and thence to interview A. who was a son-in-law of the widow Da-on and who was present at her death and during her final illness. During her illness the following sacrifices were performed to appease the "ancestors" whose *anitos* (spirits) were causing the illness: *Otóp,* a sacrifice of 3 chickens performed in Da-on's house; performed 3 separate times, not positively on 3 separate days, though probably July 1 to 3. *Sengá,* a sacrifice of 3 pigs and two chickens on July 4. *Otóp,* another *otóp* presumably to "finish" *sengá,* a sacrifice of one chicken on July 5. *Linóto,* a sacrifice of one pig on July 6; this sacrifice was no longer to save her life but to "release" her spirit and "enable" her to die. By now it was presumed that Da-on was doomed and they thought the spirit might be waiting for this *linóto* to be able to die. At dawn on July 7, Da-on died. In the early afternoon, about two, the *pano-ódan* was performed, i.e. tying the body to the *sangádil* (death chair), followed by the *magapó,* a sacrifice of one pig.

The next day, July 8, in the morning, the coffin was delivered to the grave site. About 1:00 in the afternoon the *pangeódan* was performed, a sacrifice of one pig, and the body was removed from the *sangádil.* Two men (including her son-in-law) bound up the body. The body was dressed in a special *tapis* called *kain,* a blouse, and a blanket called *kalgo.* On the head was placed a turban called *bedbed* (the ordinary word for men's turban). No beads were put in her hair. At the

grave site about five men climbed up on the ledge and pulled the body up with a rope, unbound it, stretched it at full length in the coffin and nailed on the lid. After placing the extra *kain* wrapped in paper on top of the coffin the men left without further prayers or sacrifices on the spot.

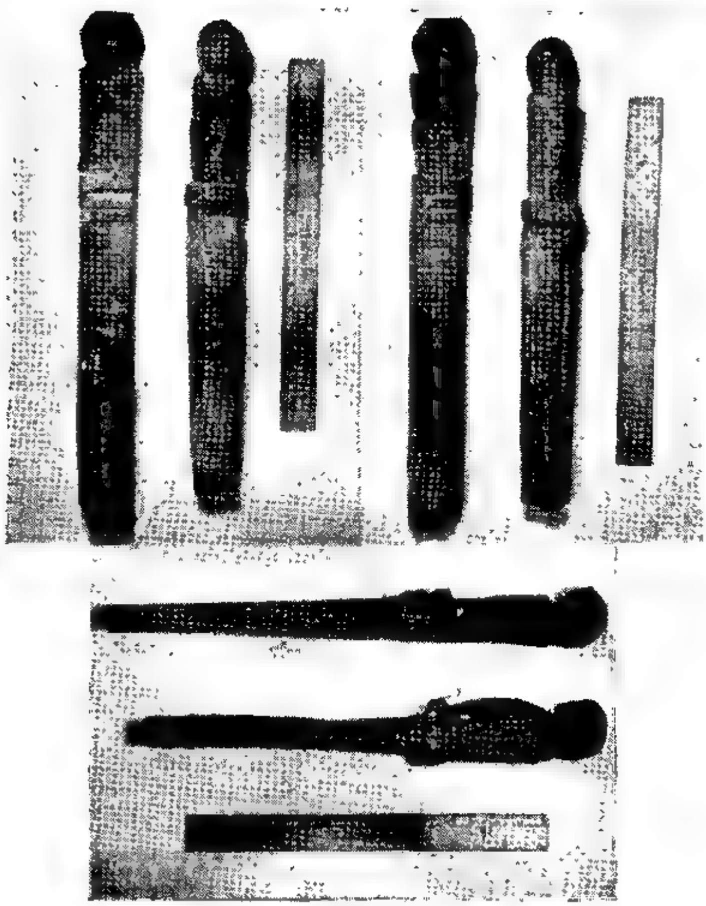
After returning home the *legleg* was performed, a sacrifice of one chicken which must be a hen, not a cock, since the cock's normal way of life would have implications of future promiscuity on the part of a surviving spouse. About a month later a *linabi* would be performed, a sacrifice of one pig in the afternoon, which is unusual as most sacrifices are done in the morning. Two weeks to a month later another *sengá* would be performed, and finally a year or more later when the family is "ready" they would perform a *lapság*, a sacrifice of two pigs and one chicken.

ILLUSTRATIONS

PLATE 1

TEXT FIGURE

1



2

PLATE 1.

BOOKS

Books received from time to time by the Philippine Journal of Science are reviewed and acknowledged in this section.

Sea Shells of Tropical West America. Marine Molluks from Lower California to Colombia. By A. Myra Keen. Stanford, Cal., Stanford Univ. Press, 1958. viii, (4), 424p. illus. plates (part col.)

In this book are well described and figured adequately about 1,600 species of marine shells found in the Panamic molluscan province. Though the book is deficient on sea shells found in Philippine waters, the author has provided conveniently keys to the classes, families, genera, and species which would be of great help to any serious students of malacology studying this particular region. The five classes of mollusks and the different species under them are thoroughly defined, discussed and well taken care of.

It is one of the best book on malacology that has ever been published in recent years, especially the part dealing on the bivalves—the author being one of the world's outstanding authorities on this group of mollusks. It is a "must" to every student of malacology and avid shell collectors on the Panamic molluscan area.

Description of the different species occurring in the region, their sizes and distribution are brief and concise, and the photographs and illustrations, excellent, rendering the book quite handy in the recognition of the various species.

This is a most valuable reference for shell collectors and malacologists, very indispensable for others concerned in the study of the marine shells of the tropical West America.—F.G.D.

Introductory Chemistry. By Lillian Hoagland Meyer. 2nd Ed. New York, The Macmillan Co., c1959. VIII, 528p. incl. illus. Price, $6.00

The text is an introductory course in chemistry primarily designed for non-chemistry majors and for students who need not take subsequent courses in chemistry. It is a good textbook for nursing, home economics, physical education, and biology majors.

The tropics are well chosen and presented in simple conversational style. Practical applications of basic principles are stressed and well illustrated. The new edition gives more ma-

terial on organic and biochemistry and updated information on textiles and radiochemistry.—I.S.S.

Elements of Calculus and Analytic Geometry. By George B. Thomas, Jr. Reading, Mass. & London, Addison-Wesley Pub. Co., Inc., c1959. x, 580p. Price, $7.50.

This is an excellent text for a one-year combined course in Calculus and Analytic Geometry with emphasis on the concepts and techniques of the calculus. The systematic, simple, and clear presentation of topics is highly commendable. The book contains many illustrative examples and problems of wide application and varying degrees of difficulty which is one of the best ways to maintain the interest of the practically-minded readers. The material is limited to essential topics suited to a brief course.

This book best serves the needs of science and engineering students with knowledge of algebra, geometry, and some trigonometry.—C.G.B.

PUBLICATIONS AVAILABLE

CONTENTS AND INDEX. THE PHILIPPINE JOURNAL OF SCIENCE, vol. 1 (1906) to vol. 10 (1915). Bureau of Science Publication No. 8 (1917). Paper, 442 pages. Price $2.00 United States currency, postage extra.

SECOND TEN-YEAR INDEX. THE PHILIPPINE JOURNAL OF SCIENCE, vol. 11 (1916) to vol. 28 (1925). Compiled by Winifred I. Kelley. Bureau of Science Monograph 26. Paper, 382 pages. Price, $2.00 United States currency, postage extra.

CHECKLIST OF THE ANTS (HYMENOPTERA: FORMICIDAE) OF ASIA. By J. W. Chapman and S. R. Capco. Institute of Science and Technology Monograph 1 (1951) new series. Paper, 327 pages. Price, $2.00 United States currency, postage extra.

NOTES ON PHILIPPINES MOSQUITOES, XVI. GENUS TRIPTEROIDES. By F. E. Baisas and Adela Ubaldo-Pagayon. Institute of Science and Technology Monograph 2 (1952) new series. Paper, 198 pages with 23 plates and 4 text figures. Price, $2.50 United States currency, postage extra.

NOTE TO CONTRIBUTORS

Manuscripts intended for publication in the Philippine Journal of Science should be sent to the Editor, Philippine Journal of Science, National Institute of Science and Technology, Manila, Philippines.

The Journal will not be responsible for the loss of unsolicited manuscripts, but those received will be acknowledged and considered promptly by the Board of Editors or other competent critics. Authors will be notified of the decision reached as soon as possible.

Manuscripts on biology must be accompanied by abstracts for publication in the biological abstracts.

Manuscripts submitted should be typed on one side of white bond paper, 8½" × 11", and double-spaced throughout. One original copy and one carbon copy of manuscripts should be submitted.

Illustrations should accompany manuscripts on separate sheets. Photographs should be sent unmounted, with serial number written on back to correspond with list of captions.

Fifty separates of each paper published in the Journal are furnished free to an author (in case of more than one author, this number is to be divided equally). Additional copies may be had at the author's expense if ordered at the time the manuscripts is submitted for publication.

The Philippine Journal of Science is published quarterly, the subscription rates per year being: Philippines, U.S. $5.00; Foreign, U.S. $6.00, plus U.S. $.50 for postage. Single issues are U. S. $1.25 in the Philippines and U.S. $1.50 in foreign countries.

Subscriptions to the Journal should be sent to the Business Manager, Philippine Journal of Science, National Institute of Science and Technology, Manila, Philippines.

Publications sent in exchange for the Journal should be addressed to the Division of Documentation, National Institute of Science and Technology, Manila, Philippines.

CONTENTS

83713